Computerised Vehicle Routing and Scheduling

in

Brewery Distribution

Peter G. Eibl

Department of Computer Studies

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Dedication

I wish to dedicate this research to my parents.

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Declaration

This is to certify that neither this thesis or any part of it has been presented or is being currently submitted in candidature for any degree other than the degree of Doctor of Philosophy of the University of Glamorgan.

Candidate...........Peter Gill...........

Certificate of Research

This is to certify that, except where specific reference is made, the work presented in this thesis is the result of the investigation undertaken by the candidate.

Candidate......Peter Gibb......

Director of Studies......R S Willis......

Computerised Vehicle Routing and Scheduling in Brewery Distribution

Abstract

Over the past twenty years academics, industry commentators and practitioners in the field of physical distribution have been pre-occupied with the computational and technical side of *computerised vehicle routing and scheduling* (CVRS). Comparatively little research activity has been carried out on the user or management aspects of the technology.

The current study aims to make up for this research deficit by investigating the adoption of CVRS technology in the British road freight industry. Moreover, the study evaluates the success of the software used in a strategic, tactical and operational role. The subject of the empirical analyses is the British brewing industry.

The findings highlight the fact that CVRS technology is used by only a relatively small number of organisations despite being an effective means to improve the efficiency of transport operations and to provide substantial intangible benefits.

The research also develops and empirically validates a *model of CVRS in the organisational context.* "Organisational context" means that the focus is on the organisational aspects rather than on the technical aspects of the technology. The model investigates relationships between variables and addresses two major research questions:

- What are the reasons leading to the apparent lack of CVRS system penetration - the "CVRS user-gap"?
- What are the key factors of successful implementations and subsequent use of the software?

To overcome the "CVRS user-gap", the study suggests appropriate measures focusing on individuals' awareness of and attitudes towards the software rather than on improving the quality of the software. To ensure CVRS success, the potential users of CVRS should have a certain level of technological and organisational maturity. Emphasis needs to be placed on adequate system implementation.

Special attention should also be given to three critical success factors:

- the quality of the software;
- the system operator's ability to use the software; and
- the drivers willingness and ability to adhere to the computer-generated route proposals.

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List of Abbreviations

b	unstandardised regression/discriminant function coefficient
b'	standardised regression/discriminant function coefficient
col.	column
CBRS(s)	computerised basic vehicle routing system(s)
CRP	computerised route planning
CVRS	computerised vehicle routing and scheduling
CVRSS(s)	computerised vehicle routing and scheduling system(s)
dev.	deviation
DP	data processing
DSS(s)	decision support system(s)
EEA	European Economic Area
EC	European Community
EFTA	European Free Trade Association
EU	European Union
incl.	inclusive
IT	information technology
NPV	net present value
OB	organisational behaviour
OBB	organisational buying behaviour
RCC	rank correlation coefficient
R^2	coefficient of determination
sign.	significant
st.	standard
TPS(s)	transaction processing system(s)
VDU(s)	visual display unit(s)
VRP(s)	vehicle routing problems(s)

Chapter 1: Introduction

"The problem: How does Santa Claus do it? Santa has a single vehicle with finite capacity that leaves from a single depot; millions of stochastic demands having tight time windows must be satisfied within a 24-hour period. I believe that the charm and challenge of VRPs[1] *are reflected in our wondering about Santa's problem, and our desire to help Santa out and get into his good graces. He knows whether we (our solutions) are good or bad".*

Saul I. Gass;
College Park, Maryland,
December 18, 1987[2]

1.1 The need for a new study

According to the *Institute of Logistics and Distribution Management 1991/92 survey of distribution costs* [ILDM, 1992] transport accounts for up to 52% of firms' distribution expenditure with the largest expenditure occurring in the food, drink and tobacco industry.

The significance of road transport is also emphasised by looking at its macro-economic dimension:

In 1991 physical distribution by road, rail and inland waterway within the European Community (EC) amounted to more than 12 billion tonnes. The major part of about 86%

1 Vehicle Routing Problems.

2 Golden, B. and Assad A. (Editors): Vehicle Routing and Scheduling, Studies and Management Science and Systems, Vol. 16, Elsevier Science Publishers B.V., North-Holland, Amsterdam, 1988, p. V.

was transported by road transport. Transport by rail and water accounted for only 8% and 6% respectively[3] [Department of Transport, 1993; Eurostat, 1993]. Prospects for road transport for the whole of the EC in the 1990s suggest a dramatic increase of between 50% and 80%, particularly in cross-border operations [Aden, 1990; Rommerskirchen, 1992]. These figures are clearly a reflection of the firms' obtaining and distributing products over greater distances, a trend which will receive further impetus from the recent completion of the Single European Market and the creation of the wider European Economic Area (EEA), incorporating European Free Trade Association (EFTA) countries.

The above facts highlight the importance of transport cost efficiency and its control, which may be managed more effectively by the use of *computerised vehicle routing and scheduling* (CVRS).

Only relatively few organisations are using CVRS technology, which is surprising, considering the availability of cheap and effective computer hardware, the general trend towards using information technology in physical distribution and the significant innovations made in CVRS technology over recent years.

The apparent lack of CVRS system (CVRSS) penetration or the "CVRS user-gap" invites the following questions:

- Is the software technically unable to meet the requirements of most organisations and, therefore, abandoned during or after implementation?
- Are operators unwilling to implement CVRS because they consider the software to be technically inadequate to meet their individual requirements?
- Do individuals and their union representatives oppose the implementation of CVRS because they are concerned about or afraid of its adverse impact on such matters as established work routines, job security and customer relations?

Past studies provide first indications that the lack of CVRS system penetration is caused by attitudinal, personal and organisational factors rather than actual deficiencies in the technology itself [Polak, 1988; Peters and Doganis, 1987; Wright and Cross, 1985;

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[3] The figures ignore the distribution of goods by inland waterway for Denmark, Greece, Irish Republic, Portugal and Spain, as these figures were not available. However, as the tonnes lifted by inland waterway account for a relatively small proportion of the total tonnes lifted, the figures provided above can be considered as representative for the overall situation.

Sussams, 1984; Cooper and Jessop, 1983]. However, the past research activity on such management (attitudinal, personal and organisational) aspects of CVRS has been rather limited. There have been few studies and most of these were small scale projects focusing on either very general aspects or a number of specific aspects of CVRS. Also, the studies were generally conducted in isolation.

Whilst management aspects of CVRS appear to have generated only limited research interest so far, past studies have led to a well-founded body of research on the mathematical or technical aspects of the technology and its underlying algorithms[4].

It can be concluded, therefore, that there is a substantial research deficit on CVRS in distribution operations. It is the intention of the current research to make a significant contribution to filling this research deficit. The research comprises a large scale empirical investigation on strategic, tactical and operational issues of CVRS in road transport with special regard to the requirements in the brewing industry.

1.2 Objectives and structure of the study

Objectives

In view of the existing research deficit on management aspects of CVRS technology and the apparent "CVRS user-gap", the current study aims to find answers to the following research questions:

- What are the overall costs and benefits of CVRS technology used in both a strategic-tactical[5] and an operational (daily) role?
- How high is the adoption rate of CVRS technology in general and, in particular, in the brewing industry?
- What are the reasons for the apparent low adoption rate of CVRS technology?
- Which are the critical success factors of CVRS technology?

[4] A list with relevant references is provided in the following Section 1.3.1.

[5] The term *strategic-tactical* stands for *strategic* and/or *tactical*.

Structure

The study is composed of nine chapters which are outlined below:

Chapter 1 introduces the subject of this study, provides definitions of terms and presents the research methodology.

Chapter 2 will briefly introduce the basics of vehicle routing and scheduling (VRS). This includes an outline of:

- the VRS function in the organisational context;
- the tasks and methods of VRS;
- the flaws of manual VRS; and
- the basic structure of CVRS.

Chapter 3 is predominantly descriptive, demonstrating the *success* of CVRS technology in terms of costs and benefits as well as user satisfaction. The results are based on a *consensus* survey conducted in the brewing industry.

Chapter 4 is also predominantly descriptive as opposed to analytical. It investigates the adoption rate of CVRS technology in the brewing industry and in the road transport industry as a whole. This includes the identification of both the current and potential number of CVRS users in both industries.

Chapter 5 presents a research framework - the *CVRS model in the organisational context.* The model is composed of two sub-models:

- *CVRS adoption model*
- *CVRS success model*

The Chapter also outlines the statistical procedures used to validate the models.

Chapter 6 and **7** are purely analytical testing the *CVRS adoption model* and the *CVRS success model* respectively. This is carried out with data mainly collected in the brewing industry.

Chapter 8 presents a critical evaluation of the *CVRS models* and suggests opportunities for their future development.

Chapter. 9 summarises the findings of the study and draws conclusions on how to overcome the CVRS user-gap and what measures can be taken to ensure that CVRS technology is successful.

1.3 Definitions

1.3.1 Vehicle routing and scheduling (VRS)

Basic *vehicle routing* (VR) is defined here as the planning of the delivery and/or collection of goods using one or more road vehicles. VR becomes *vehicle routing and scheduling* (VRS) when time constraints are incorporated. The objective of both VR and VRS is to construct a feasible set of minimum-cost routes - one for each vehicle. VRS problems in distribution operations are generally further complicated by a variety of constraints such as limited access to customer premises or precedence relationships, that is, one customer outlet must be serviced before another.

In the literature and among practitioners in physical distribution the VRS problem or variations of it are frequently referred to by synonyms such as *load planning* [Cooper and Jessop, 1983], *vehicle-load planning* [Sussams, 1984], *vehicle round planning* [Peters and Doganis, 1987] and *round planning* [Peters, 1990].

To add to the confusion, the terms "*vehicle routing*", "*vehicle scheduling*" and the combination of both terms "*vehicle routing and scheduling*" are often used to specify certain aspects of road vehicle transport problems. It is also not unusual to find the terms being used as synonyms for one another.

Given the apparent lack of a generally acknowledged classification of the terminology used to describe road transport problems, the current research makes no attempt to elaborate on this in further detail. Instead, the interested reader may be referred to a selection of appropriate literature. This includes the works of Thorpe [1992], Domschke [1990], Golden and Assad [1988], Pape [1988], Ziegler et al [1988], Brendel [1987], Sorensen [1986], Waters [1986], Belardo et al [1985], Domschke [1985], Hellmann [1984], Bodin et al [1983], Ellinger et al [1982], Bodin and Golden (1981), Christofides

[1981], Paessens [1981], Ellinger [1980], Probol [1979], Nagel [1978], Matthäus [1978], Vaterrodt [1974] and Kreuzpainter [1972].

1.3.2 Computerised vehicle routing and scheduling (CVRS)

The current research differentiates between three types of software system used for the planning of delivery activities of road vehicles.

- ***Computerised vehicle routing and scheduling systems*** (CVRSSs) are defined as systems which solve the basic *VRS* problem as outlined above. CVRSSs are usually commercially available, highly sophisticated interactive systems, based on complex mathematical programming, graphic displays and effective user interfaces. These systems are suitable for applied transport problems with complex delivery constraints such as time windows and limited access to customer premises. Typical CVRSSs are the commonly known packages ***Routemaster*** and ***Paragon2*** [6].

- ***Computerised basic routing systems*** (CBRSs) are defined as systems which determine the shortest route (in terms of time or distance) between two locations within the road network. Typical CBRSs are the popular packages ***Autoroute Plus*** and ***Milemaster***. Some of the currently available CBRSs also cope with the *Travelling Salesman Problem*[7] and, to some extent, with simple VR problems involving more than one vehicle.

- ***Computerised order allocation systems*** (here referred to as ***order allocation software***) are defined as systems which allocate orders to routes or vehicles. Order allocation software is (usually self-developed or customised) simplistic software which is not based on any complex algorithm. It can be thought of as the automation of the manual VRS system. Orders are pre-allocated to routes with the number of orders per route depending on the prevailing order quantity.

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[6] A list of some of the most popular CVRSSs available on the British market is shown in Appendix 6, p. A-38.

[7] "The classical *Travelling Salesman Problem* requires the determination of a minimal cost cycle that passes through each node in the relevant graph exactly once" [Bodin et al, 1983, p. 79].

1.3.3 Other definitions

Following Sanders [1984] the current research divides computer-based information systems into one of three types:

- ***Transaction processing systems*** (TPSs) are defined as systems which are "concerned with the efficiency of routine organisational processes" [Sanders, 1984 p. 31]. Typical TPSs in physical distribution are payroll systems or order entry and processing systems.

- ***Management information systems*** (MISs) are defined as management oriented systems that "monitor and retrieve data from the environment" [Goslar et al, 1986, p. 79]. Typical MISs in physical distribution are stock and inventory control systems or vehicle fleet information systems.

- ***Decision support systems*** (DSSs) are defined as flexible interactive "man-machine decision systems in which the computer is used to serve decision makers" [Welsch, 1981, p. 206] and "to assist decision makers in dealing with semi-structured or unstructured problems" [Goslar et al, 1986, p. 79]. Typical DSSs in physical distribution are inventory planning systems or warehouse design systems.

  According to the above definitions CVRSSs belong to the category of ***DSSs***. The software's primary function is to generate a route proposal. On this basis the system operator (scheduler) decides what steps to take next. The scheduler can either accept the proposal or decide to adjust it as appropriate, according to his/her specialised knowledge of a particular delivery situation.

  Decision factors for adjusting the route proposal may be the occurrence of unexpected road closures, changes in time windows or the need to spread the workload evenly over the drivers available. Having decided to adjust the route proposal, the scheduler can modify some planning parameters and request a new automatically generated route proposal for all orders or for a selection of orders. Alternatively, the scheduler can adjust the route proposal manually using the keyboard or a mouse.

1.4 Methodology

1.4.1 Research methods

The methodological framework of this research consists of

- secondary research methods (desk research) and
- primary research methods (field research).

Secondary research

The secondary research includes an extensive initial and on-going survey of literature in Germany and, predominantly, Great Britain. The literature search was supported by the use of the on-line data base INSPEC[8] facility offered by the library of the University of Glamorgan.

The extensive literature search provided essential background information to the formulation of the study's basic objectives, hypotheses and associated research instruments. Moreover, it made a significant contribution towards the underlying *long-term multi-person research* objective of analysing, systematising, and consolidating the results of previous studies [Kubicek, 1975b] in the area of CVRS.

Primary research

This study uses a combination of both **quantitative** research methods based on surveys and **qualitative** research methods based on case studies as well as expert interviews [Yin, 1984]. The combination of both methods, also known as the *triangulation of measurement* approach, is likely to generate greater confidence in the findings and/or to enhance the findings of the investigation [Bryman, 1988].

While the *triangulation of measurement* approach is probably one of the most challenging and difficult empirical research designs to carry out, it can be considered the most powerful one. Its strength lies in its flexibility to apply either method as appropriate, depending on the particular research aspects concerned. For certain aspects predominance may be given to quantitative methods, while for other aspects the

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8 The database is maintained by the Institute of Electrical Engineers (IEE).

qualitative methods are more effective. Ideally, both methods are used to provide evidence concerning the same research aspects, thus providing mutual confirmation.

Collection of empirical data

According to the CVRS suppliers interviewed in this study, only approximately 240 organisations were using CVRS in Britain at the outset of the current project in late 1991. This small number of users did not allow for a survey based on *random sampling*, as the response rate was likely to be insufficient for a meaningful analysis. Neither was a *consensus* survey of all users feasible, since only limited information was available about the users' names and addresses.

Therefore, the data for both the quantitative and qualitative research of current, potential and past users of CVRS were collected predominantly in the brewing industry of Great Britain. The study's approach of focusing on a single sector has the advantage of being feasible within the financial and organisational constraints of the project. Moreover, it enables the use of CVRS to be investigated within a uniform operating environment, thus facilitating the data analysis and subsequent interpretation of results. Also, the chosen approach allows for a more detailed investigation of the specific benefits, problems and organisational consequences in organisations with the same overall requirements. Several methodological and practical aspects led to the selection of the brewing industry as the primary object of analysis, as briefly outlined below:

- Firstly, and perhaps most importantly, the author of this research was aware of several CVRS users in this industry.

- Secondly, the relatively small size of the industry allows for good control over the data collection thus enhancing the reliability of the results.

- Thirdly, the brewing industry has a long history of using CVRS technology and therefore contains a relatively large number of CVRS users. In fact, some of the early CVRS packages were developed from experience gained in the brewing industry.

- Fourthly, the industry's standard VRS problem, which is characterised by *depot-bound multiple deliveries*, is ideal for solution by current CVRS technology[9].

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[9] The transport problems of the brewing industry will be discussed in Section 2.5.

- Finally, breweries operate in a highly restrictive distribution environment characterised by short order lead times, high delivery frequencies and tight time windows. If CVRS can be shown to be successful in this sector of road transport, extrapolation of the findings may suggest that the software also performs successfully in sectors with similar basic transport problems and equally or less restricted operating environments.

However, to give the research the widest possible scope, the analyses are also related to the road transport industry as a whole where appropriate. This will lay the foundations for the ultimate objective of relating the study's brewery-specific findings to other sectors of road transport.

Confidential treatment of data

The collection of extensive and highly detailed empirical data relating to current, potential and past users of CVRS technology as well as the suppliers of the software was only made feasible with the author's assurance of strict confidentiality. Therefore, all organisations which have kindly participated in the research are referred to by pseudonyms. Similarly, CVRS packages are named by pseudonyms if mentioned in relation to commercially sensitive data supplied by the software suppliers.

However, to minimise the *abstraction* effect caused by the use of pseudonyms, the packages will be referred to by their actual names when mentioned in relation to their use by fleet operators. Also, there will be a description of the basic structure of those companies which are subject to case studies and are, therefore, frequently referred to in the text (see following Table 1.1)[10].

This procedure is considered to be a fair compromise between the confidentiality assured to the parties involved in the research and the interest of the reader of this study.

To avoid any misinterpretation of the findings on individual CVRSSs, the author wishes to stress that, with the exception of the comparative studies in Sections 7.3.3 and 7.5.3, this research highlights positive or negative technical aspects of certain CVRSSs rather randomly as opposed to systematically. The information was given by individual organisations and has not been verified by the author.

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[10] Appendix 5 (p. A-37) provides a list of the actual names of all organisations which have participated in this study.

In fact, it is important to realise that the research by no means aims to provide a full technical analysis of the quality of all CVRS packages available. There are several good reasons for this, three of which are briefly presented below:

- Firstly, and most importantly, the research aims to investigate the adoption and success of CVRS technology as such and not which individual packages are more or less successful than others.

- Secondly, the CVRS market is highly dynamic with individual packages being modified significantly within small time scales. A system, which is the market leader at one point in time, may no longer be so in the following year. Equally, a less successful CVRSS may be given a major update; for instance, its deficient road database developed in-house may be replaced by a highly sophisticated road database from a commercial mapping agency. This amendment may turn a less effective CVRSS into a top-performing package within a very short period.

- Thirdly, even if CVRSSs did not change significantly over time, a meaningful analysis of their quality would require objective measures which are quite difficult to develop. Ideally, each CVRSS needs to be tested with several sets of empirical distribution data, perhaps categorised by the level of complexity in terms of the road network, number of daily customers and number and type of delivery constraints. This will be necessary because benefits or problems of a particular CVRSS used in one company may not apply if used in another company.

  The CVRSSs also need to be tested under the same circumstances, that is in a laboratory environment by the same system operators (schedulers). Ideally, the computer-generated routes would be tested in the field by the same drivers who carry out deliveries on the basis of the routes.

1.4.1.1 Qualitative research

The qualitative research methods used in this research are:

- interviews with suppliers of CVRS technology (subsequently referred to as "expert interviews"); and
- in-depth case studies of current, potential and past users of CVRS technology.

Expert interviews

Expert interviews were the starting point of the research. Face-to-face and telephone interviews were conducted with all suppliers of CVRS technology in both Britain and the former West Germany. Interviews with German CVRS suppliers were held because at the outset of the project it was planned to investigate the use of CVRS technology in a comparative study between the two countries. For practical reasons, it was later decided to focus the research effort on the British CVRS market. The latter included a total of nine suppliers[11] at the end of 1993.

The British suppliers were identified from the author's background reading of CVRS literature, the annual *ILDM Guide to Distribution Software*[12] [Andersen Consulting, 1993], various commercial trade journals and visits to the annual *ILDM Exhibition* at the National Exhibition Centre (NEC) Birmingham.

The expert interviews gave the initially required special technical knowledge of CVRS. Moreover, they established the first contacts with organisations using the software. The relationships between the author of this research and the CVRS suppliers were developed and continued throughout all phases of the study. These proved to be a valuable source of information. It also enabled the researcher to discuss technical issues and to seek advice on matters of applied CVRS, as appropriate, throughout all stages of this study.

Case studies

The main vehicle of the qualitative research is its *multiple case study design* [Yin, 1984] based on in-depth interviews with current, potential and past users of CVRS technology. Moreover, several informal interviews were held with potential users of CVRS technology. Generally speaking, the case studies provide unique, rich and comprehensive evidence on the benefits, problems and organisational consequences of using CVRS in distribution operations. Case studies are of particular value for the analysis of complex issues such as the CVRS implementation process where quantitative research methods provide no results or only limited ones.

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[11] A list of British CVRS suppliers is presented in Appendix 6, p. A-38.

[12] The *ILDM* (Institute of Logistics and Distribution Management) was recently renamed the *IL* (Institute of Logistics). Analogously, the *ILDM Guide to Distribution Software* is now called the *IL Logistics Software Guide.*

Moreover, as one of the key benefits of the *triangulation of measurement* approach, the qualitative case study research has been helpful for the subsequent quantitative or survey research [compare: Sieber, 1973; Stinchcombe, 1964]. This was achieved in several ways as follows:

- Firstly, the case studies established the basis of confidence which was necessary to gain the organisations' interest and willingness to participate in the survey. This was particularly important with respect to certain large organisations using CVRS technology. In fact, as a result of the close contact established during the case study research, some organisations agreed to administer highly detailed and comprehensive research questionnaires at all (or the majority) of their distribution sites at a national level.

- Secondly, the case study research helped in the formulation of research hypotheses, including the operationalisation of variables and the construction of scales as well as indices.

- Finally, the case studies were very useful in the analysis and interpretation of the relationships between variables described by quantitative data, in particular by allowing some insight into the causal processes.

In total, more than 16 case studies of current CVRS users from several sectors of the road transport industry in both Britain and Germany have been conducted (see following Table 1.1). There are two types of case study:

- **in-depth case studies,** and

- **general case studies.**

In-depth case studies were compiled with respect to 11 organisations or *independent operating centres* of organisations with *decision-making authority* to purchase and implement CVRS[13]. Such independent operating centres may have control over one or more distribution sites. The data were collected predominantly via single or multiple

[13] An organisation may include one or more *independent operating centres* which have *decision-making authority* in relation to the purchase and implementation of CVRS technology (subsequently referred to as "*CVRS decision-making authority*"). Hence, as far as the brewing industry is concerned, the research looks at such *independent operating centres* as opposed to *organisations*. This issue will be further explained in Section 4.2.3, p. 99f.

diagnostic face-to-face interviews which lasted up to eight hours each. These were supported by follow-up telephone conversations and self-completion mailed questionnaires. In order to structure the collection of data as well as to facilitate the classification and interpretation of the data obtained, each interview was structured using an in-depth *standardised questionnaire* [Yin, 1984]. The questionnaire served as a general guideline for the interviews, which still remained open-ended and assumed a conversational manner.

General case studies were carried out on five independent operating centres with CVRS decision-making authority. The data were collected predominantly via telephone conversations and self-completion mailed questionnaires.

It is important to realise that case studies were compiled for nearly all *independent operating centres* using CVRS in the British brewing industry. These operating centres include, among others, the industry's five largest brewing groups. Only one operating centre using CVRS, which is an independent brewery, was unable to participate in the research due to lack of time. Hence, the multiple case study design is comparable to a *consensus* survey which gives strong support for the generalisation of the study's findings within this particular industry.

The users of CVRS were identified from the author's background reading and a telephone survey using references obtained from brewery-specific statistics and reference indices. The course of this survey and the exact reference material used will be discussed later[14].

Table 1.1 overleaf gives an overview of all case studies conducted on current and past users of CVRS.

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[14] See Section 4.2.3, p. 99f.

Type of case study 1)	Name (Pseudo-nym)	Sector	De-pots 2)	Ave-rage ve-hicles/ depot	Average daily orders/ depot	Average an-nual delive-ry volume/ depot (tonnes)	CVRS package used3)
ICS	Brewery-A	Brewing	>10	24	200	72,000	Visit (O), DiPS (S-T)
ICS	Brewery-B	Brewing	>10	23	250	75,000	Routemaster(O, S-T)
ICS	Brewery-C	Brewing	>10	25	250	61,000	Visit (O), Routemaster (O, S-T)
ICS	Brewery-D	Brewing	1	18	200	25,000	DiPS (O, S-T)
ICS	Brewery-E	Brewing	1	30	230	100,000	Dayload (O)
ICS	Brewery-F	Brewing	1	15	145	26,000	Paragon2 (O)
ICS	Brewery-G	Brewing	1	35	280	200,000	Dayload (O, abandoned) DiPS (O, S-T)
ICS	Brewery-H	Brewing	4	46	420	120,000	Dayload (O, abandoned) Paragon2 (O)
ICS	Brewery-I	Brewing	>10	20	240	45,000	Paragon2 (S-T)
GCS	Brewery-J	Brewing	1	10	80	28,000	Routemaster (O)
GCS	Brewery-K	Brewing	1	13	70	20,000	Dayload (O)
GCS	Brewery-L	Brewing	1	63	500	180,000	Visit (O)
GCS	Brewery-M	Brewing	1	17	250	26,000	Dayload (O, abandoned)
GCS	Brewery-N	Brewing	4	40	275	88,000	Visit (O)
ICS	Company-O	Kitchen furniture	1	66	500	not known	Optitour (O)
ICS	Haulier-Q	Contract distribu-tion	4	110 (all de-pots)	3,000 (or-ders are planed centrally)	not known (30-40 orders per daily route)	PMS Realtour (S-T, abandoned during current research)

1) "ICS" = In-depth Case Study; "GCS" = General Case Study

2) The number of depots of the large brewing groups is not specified precisely. The aim of this is to avoid the identification of the organisations' names.

3) "O" = Operational CVRS; "S-T" = Strategic-Tactical CVRS

Table 1.1: Overview of case studies of current and past users of CVRS

1.4.1.2 Quantitative research

Quantitative data, as opposed to qualitative data, is often depicted as *hard*, *rigorous*, and *reliable* [Bryman, 1988]. Therefore, the major strength of quantitative research is undoubtedly its ability to allow for the statistically founded generalisation of results. Ideally, the *hard* data of quantitative research empirically confirm the *soft* data of the qualitative approach.

The quantitative research conducted here consists of two surveys based on self-administered questionnaires including:

- a survey of British suppliers of CVRS technology; and
- a survey of current, potential and past users of CVRS technology in the British brewing industry.

Moreover, some preliminary case studies were compiled for several companies in the soft drinks industry, road haulage industry and kitchen furniture industry of the former West Germany.

a) Survey of CVRS suppliers

Survey population and data collection

A self-administered questionnaire survey was carried out on all nine suppliers of CVRS technology in Britain[15]. Hence, this is a consensus survey where the *selected sample* includes the *total population.*

Questionnaire design and pre-test

The questionnaire was designed on the basis of the author's background reading and preceding qualitative research. Moreover, the questionnaire was revised and pilot tested by two CVRS suppliers who had a strong involvement in the research throughout all of its phases. The repeated completion of the questionnaire by these two suppliers is likely to have no adverse effect on the validity of the data collected by the final questionnaire. This is because the questionnaire refers only to objective or factual data as opposed to subjective or attitudinal data. As far as attitudinal data are concerned, the repeated measurement of variables relating to the same individuals carries the risk of biasing responses.

The questionnaire covers three areas as follows:

- the use of the software (e.g. number and sectors of organisations using CVRS packages);

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[15] See Section 1.4.1.1 ("Expert interviews"), p. 12.

- technical features and purchase price of the software; and
- the suppliers' marketing activity.

To keep the research within a reasonable length, not all of the data provided from this questionnaire survey have been used in this final version of the thesis. Therefore, the original questionnaire, which comprises more than 25 pages and 44 items, is not included in this research document. However, the document includes the relevant questionnaire items or indicators used for the testing of the hypotheses. The indicators will be referred to in the text by their labels which then allows the original indicators to be identified.[16]

Administration and response rate

Copies of the questionnaire were mailed to the suppliers between December 1993 and January 1994. They were completed and returned between January and March 1994 by eight out of the nine (89%) suppliers. For reasons of confidentiality one supplier was reluctant to complete a questionnaire. However, it was possible to collect some of the data required for the research via telephone conversations with the supplier as well as by analysing the above mentioned *ILDM Guide to Distribution Software* and trade magazines[17].

b) Survey of current, potential and past users of CVRS in the brewing industry

Survey population and data collection

The data were collected from own-account operators in retail distribution in the British brewing industry; that is secondary distribution from brewery depots with multiple delivery vehicles delivering to pubs, clubs and similar customers. Excluded from the survey are own-account fleets of breweries which deliver mainly via single-delivery operations to the take-home market such as large supermarkets[18]. Also excluded are contract distributors.

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[16] See Appendix 1, p. A-1. The process of identifying the original questionnaire items will be further explained in Section 1.4.2.1, p. 25f.

[17] See Section 1.4.1.1 ("Expert interviews"), p. 12f.

[18] The different types of brewery distribution will be further described in Section 2.5, p. 39f.

The data were collected predominantly by self-administered questionnaires. There were two general types of questionnaire - one for brewery sites using commercially available *CVRS technology* and one for sites using manual planning techniques or simplistic *order allocation software*[19].

The hypotheses tested with survey data relate to different populations. Some hypotheses concern individual groups only, these being managers, schedulers or drivers. Moreover, certain hypotheses relate to sub-groups within a group. For instance, the hypotheses regarding factors which affect an organisation's decision to implement CVRS, are tested with the data sub-set relating to managers with *CVRS decision-making authority* excluding managers without *CVRS decision-making authority.* In contrast, other hypotheses regarding, for instance, factors associated with the managers' satisfaction with CVRS are tested using the responses of managers with and without *CVRS decision-making authority.*

As far as the independent operating centres with *CVRS decision-making authority*[20] and corresponding managers are concerned, the selected sample includes 100%[21] of the population. These are 13 current CVRS users and 34 potential CVRS users (or managers with *CVRS decision-making authority*). The operating centres had been identified from a preceding market survey based on addresses obtained from various sources of statistical material[22].

In the case of three operating centres with *CVRS decision-making authority* each of which represents a large brewery group using operational CVRS at several depots, questionnaires were also sent to the depots' managers (managers without *CVRS decision-making authority*[23]) and schedulers. For one brewery group, the *selected sample* includes all of its 11 depots using CVRS. As to the two other brewery groups, the *selected sample* includes 6 depots out of 13 (46%) and 11 out of 17 (65%) respectively. The latter samples were determined at random to ensure that they represent the total number of the groups' depots using the software.

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[19] See definitions in Section 1.3.2, p. 6.

[20] See Section 1.4.1.1 ("Case studies"), p. 12f.

[21] Note that the achieved samples or the response rates are, depending on the hypotheses tested, typically 80% and in some cases up to 93% of the *selected samples*.

[22] Section 4.2.3 (p. 99f) will outline the procedure of the market survey in further detail.

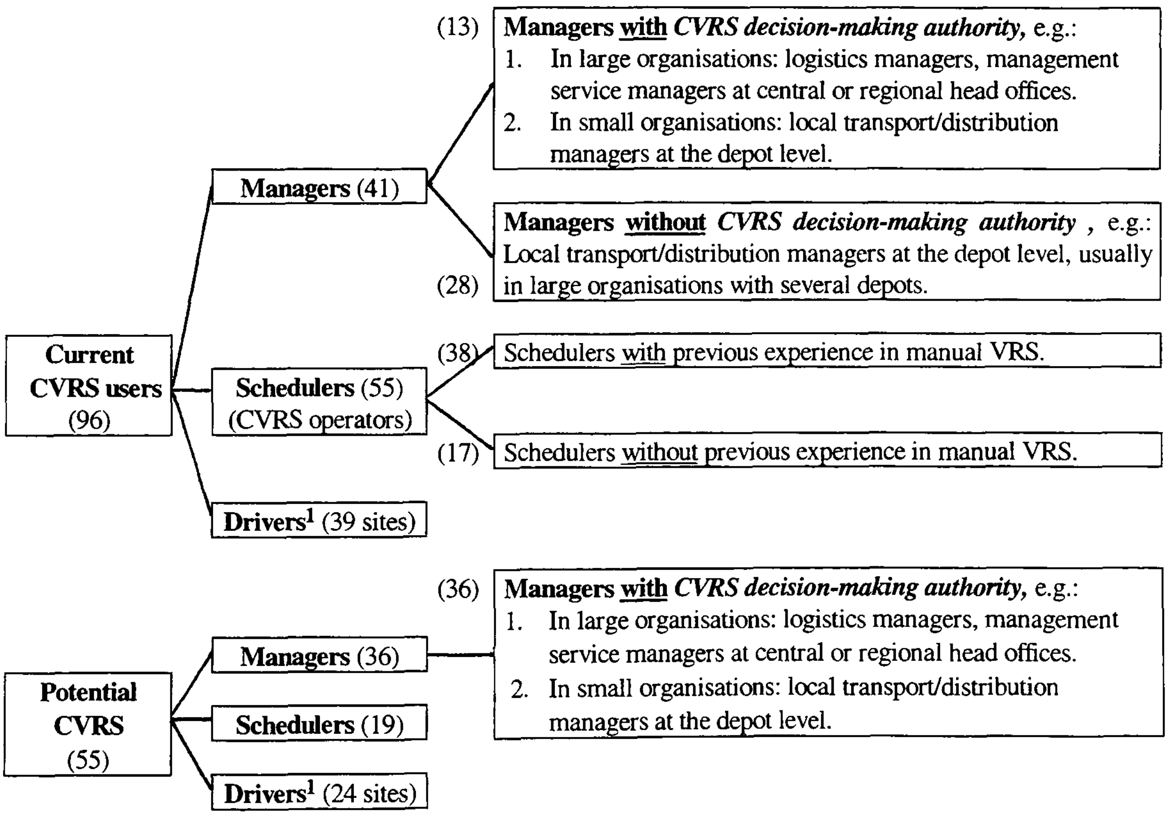
[23] See Figure 1.1, p. 19.

In summary, data were collected from a total of 151 individuals in 49 *independent operating centres* with *CVRS decision-making authority*[24] and their associated operational distribution planning sites (depots) or strategic distribution planning sites (e.g. logistics departments, management service departments) . These 151 individuals are composed of:

- 96 individuals from sites using CVRS (current CVRS users); and

- 55 individuals from sites not using CVRS (53 potential and two past users of CVRS).

The data collected from both current and potential CVRS users relate to three groups of individuals: managers, schedulers and drivers as shown in the following Figure 1.1 which is further explained below.



[1] Note: The drivers have indirectly participated in the survey in that the managers and schedulers responded on their behalf.

Figure 1.1: Respondents to the survey of CVRS usage in the brewing industry

[24] See Section 1.4.1.1 ("Case studies"), p. 12f.

- Managers: There are two sub-groups of managers differentiated by the criterion of whether or not they have *decision-making authority* regarding the purchase and implementation of CVRS ("CVRS decision-making authority"):

CVRS decision makers

In large organisations with several depots the managers with *CVRS decision-making authority* are usually located in logistics departments, distribution departments, data processing departments or other similar service departments at the central or regional head offices. It is important to realise that, depending on the organisational structure of companies, there can be several managers with *CVRS decision-making authority* within a single organisation. For instance, one national brewing company participating in this research is divided into three regions or independent operating centres each of which has its own *CVRS decision-making authority* and associated manager.

In smaller organisations the *CVRS decision makers* are usually transport or distribution managers at the depot level.

In total the research includes 13 managers with *CVRS decision-making authority* from sites using CVRS and 36 such managers from sites not using CVRS.

CVRS non-decision makers

Managers without *CVRS decision-making authority* are usually the local depot or distribution managers of large organisations with several depots. As indicated by their designation, these managers have not been directly involved in decisions regarding the purchase and implementation of CVRS. The research includes 28 such managers. The inclusion of local depot managers without *CVRS decision-making authority* of sites aims to collect "first hand" information on the use of the software in an operational role.

- Schedulers: Schedulers are members of staff carrying out the VRS function. In companies using CVRS the schedulers are also referred to as "*CVRS operators*". With regard to CVRS operators there are two types - one with previous experience in manual VRS and one without manual experience in VRS. The differentiation is important in relation to certain questionnaire items which refer to the schedulers' perception of the difference between manual VRS and CVRS. These items were only addressed to the system operators with experience in manual VRS.

In total, the research is based on responses given by 55 schedulers from sites using CVRS and 19 schedulers from sites not using CVRS.

- Drivers: This research was unable to administer a questionnaire directly to the drivers of the participating organisations. Instead, the data regarding the drivers were provided by the managers and schedulers who responded on behalf of the drivers as a group. Their responses were averaged. Such provision of evidence from more than one source enhances the validity of measurement.

There are a number of practical, organisational and methodological reasons in favour of asking managers and schedulers to respond on behalf of their organisations' drivers:

- Firstly, if the responses were given by the drivers themselves, it would have required the taking of a statistically representative and therefore fairly large random sample of all drivers within a single organisation. The breweries involved in this study were generally reluctant to administer such large numbers of questionnaires. The reluctance was highest among breweries not using CVRS technology, as these were concerned that the issue of CVRS might have led to confusion among the drivers.

- Secondly, the breweries participating in this study failed to provide sufficient information about the identity and personal characteristics of their drivers. Also, the breweries were generally unwilling to establish direct contact between their drivers and the author.

  The lack of information about the drivers would have negatively affected both the administration of the questionnaires and the evaluation of the risks of *bias* in the responses. For instance, the questionnaires might have been completed by drivers with a particular interest in the research subject. Such a biased *sample* would have been non-representative for the total population.

Some assurance of the validity of the managers' and schedulers' responding on behalf of the drivers is provided by the fact that the responses given are similar overall. Nearly all responses indicate the same direction and the majority of responses correlate significantly.

Nevertheless, the final assessment of the validity of this measurement technique depends on the nature of the variables investigated. There are two groups of variables pertaining to drivers:

- The first group comprises behavioural or non-cognitive variables such as **drivers' performance** (the drivers demonstrated willingness and ability to adhere to the standards indicated by the computer-generated route plan) and **drivers' involvement** in the implementation of the software.

- The second group of variables concerns the drivers' mental states or cognitive processes, for example, **CVRS user satisfaction** (drivers' satisfaction with the software), **CVRS pre-attitudes** (drivers' pre-implementation attitude towards the software) or **conviction of CVRS success** during the software implementation.

The variables in the first group can best be evaluated in the proposed manner; that is, by their superiors (managers) and close colleagues (schedulers). This measurement is likely to provide a better estimation of the actual **drivers' performance** than if it were measured by the drivers, because they may give biased responses to protect their reputation.

In contrast, as far as the variables of the second group are concerned, there is undoubtedly some methodological weakness in the chosen approach of asking a third person to respond on behalf of others. However accurately the managers' and schedulers' responses may reflect the drivers' actual attitudes and satisfaction which are the subject of the investigation, some error and thus invalid evidence is bound to occur. Therefore, the results concerning the drivers' attitudes and satisfaction are only used as <u>indications</u> as opposed to <u>firm evidence</u>.

In total the research is based on ratings given by both managers and schedulers on behalf of drivers at <u>39</u> sites using CVRS and at <u>24</u> sites not using CVRS.

Questionnaire design and pre-test

- <u>Research variables:</u> The questionnaires including the research variables were designed on the basis of the qualitative data collected from the previously conducted case studies and expert interviews. This design-process was accompanied and supported by suggestions given by academics from various disciplines (computing, business management, social science) at the University of Glamorgan.

- Scales: The selection of scales was made on the basis of consulting standard statistics text books and by looking at past empirical studies of predominantly MISs and DSSs. To facilitate the completion of the questionnaires, most items or indicators have been measured by the commonly used *Likert type five-point scale* and *semantic differential seven-point scale* [compare: McDaniel and Gates, 1991].

- Pre-test: Due to the extremely small size of the total survey population there was only limited scope for pre-testing the questionnaires without "wasting essential *data resources*". This testing was performed by a total of five managers and six schedulers from organisations using CVRS. In addition, the *CVRS* user-questionnaire was pre-tested by two managers from depots (of a national brewing group not using CVRS in an operational role) which were using *order allocation software*[25] as opposed to CVRS. The pre-testing of a CVRS user-questionnaire by a CVRS non-user is considered methodologically acceptable, because the respondent is "similar to the one who will eventually complete the survey" [Fink and Kosecoff, 1985, p. 50].

No pre-test was carried out on the questionnaires addressed to potential users or non-users of CVRS. This procedure is also considered to be acceptable, since the questionnaires of the potential CVRS users do not include any items which are not also included in the questionnaire of the current CVRS users. Differences between the two groups only concern the phrasing of certain items in terms of the time when events have occurred[26].

Further support for the usefulness and validity of the questionnaires is provided by the fact that they are based on the *standardised* interview guides used for the previously conducted case studies. Hence, the questionnaires had already been tested indirectly throughout the extensive qualitative research. A similar procedure is suggested by Rogge [1981] according to whom *intensive discussions* of the questions with a member of the sample (expert in this sense) can be sufficient or useful to satisfy the requirements of pre-testing.

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25 See Section 1.3.2, p. 6.

26 Section 6.2 will outline this issue in further detail.

Administration and response rate

- Operational CVRS: The self-completion questionnaires were mailed in Spring 1992.[27] The majority of questionnaires were returned during the early summer of 1992. Because of the considerable length and level of detail of the questionnaires some respondents failed to answer certain items. Also, some respondents appear to have given inconsistent answers which can occur when responding to large numbers of items. In these cases, the missed or apparently inconsistently answered items were returned to the respondents for confirmation as appropriate.

  In general, the hypotheses relating to the adoption and success of CVRS used in an operational role were tested on the basis of the *achieved samples* of typically 80% and in some cases up to 93% of the *selected samples.* For one hypothesis (*hypothesis 2b*) relating to the current and potential use of CVRS the response rate amounts to 100%.

- Strategic and/or tactical CVRS: The empirical research on the use of CVRS technology in a strategic and/or tactical role (subsequently referred to as "strategic-tactical CVRS") was also carried out as a *consensus* survey; that is, the *selected sample* includes the *total population*, i.e. 17 strategic planning sites[28].

  Data were collected from all of these 17 sites, most of which are allocated to the brewery companies participating in the survey on CVRS used in an operational role. Hence, the *achieved sample* is 100%. Because of the small number of *independent operating centres* using strategic-tactical CVRS technology, the responses are analysed exclusively by univariate statistics using frequency counts.

  The data were collected by the same questionnaires as were employed to investigate the use of CVRS used in an operational role. Data relating to an additional brewing group with one current and two potential strategic-tactical CVRS distribution planning sites were collected via face-to-face (in-depth case study) and telephone interviewing.

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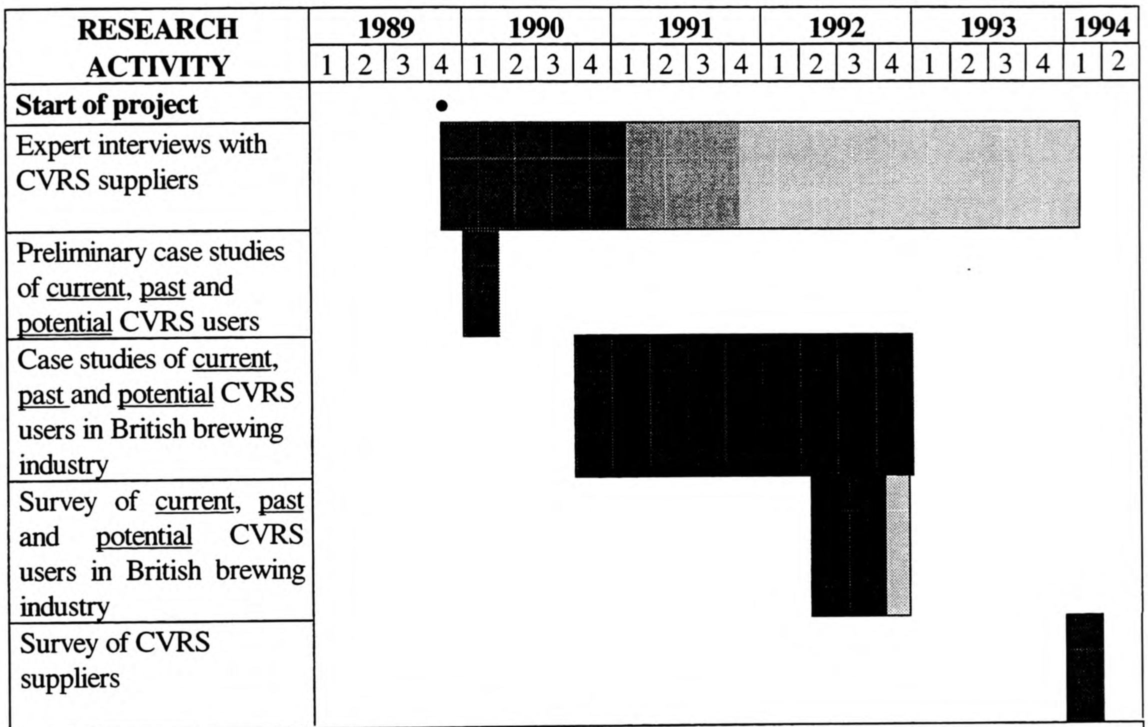
27 See Section 1.4.1.2 ("Survey of current, potential and past users of CVRS in the brewing industry"), pp. 17-18.

28 Section 4.3.3.1 (p. 117f) describes this aspect in further detail.

1.4.1.3 Summary of research methods

Figure 1.2 summarises the schedule of both the qualitative and quantitative research methods applied in this research.



Note: The intensity of the shading indicates the intensity of the research activity in terms of data collection

Figure 1.2: Schedule of quantitative and qualitative research methods

1.4.2 Measurement of variables

1.4.2.1 Operationalisation of variables

The objects of analysis used in hypotheses are commonly referred to as *variables* [Lucas et al, 1990; Joseph, 1990; Gross, 1989; Ein-Dor and Segev, 1981; Kubicek, 1975b; Lucas, 1975]. To be able to measure the variables they need to be given an *operational* definition. This process is known as "*operationalisation*" of variables [Schnell et al, 1993; Gross, 1989; Ein-Dor and Segev, 1981; Steers, 1975].

Following Schnell et al [1993] and Bryman [1988], the operationalisation of a variable in the current research is a multiple stage process, as shown in Table 1.2.

1	2	3	4	
Concept	**Dimension**	**Sub-dimension**	**Indicator* (contents)**	**Indicator (label)**
-	+ General CVRS pre-attitude	(not applicable)	General usefulness of CVRS	C-5
			General importance of CVRS for company's physical distribution	C-7
			General benefits provided by CVRS	C-9
CVRS pre-attitude	Attitude towards CVRS quality relative to distribution environment	+ Transport	Capability of CVRS to deal with delivery constraints	C-34
		+ Warehouse A	Financial justification for installing CVRS at all depots	C-35
		Warehouse B	Organisational justification for installing CVRS at all depots	C-36
		Warehouse C	Capability to achieve cost savings in customer allocations	C-37
		Warehouse D	CVRSS's impact on order picking and assembly	C-38i
		+ Service A	Customers' willingness to accept change in service	C-39
		+ Service B	Impact of change in service on customers' goodwill	C-40i
		Service C	Customers' view of CVRSS's impact on service level	C-41
		Service D	Ability of CVRSS to deal with late customer orders	C-42

* For convenience, the ***indicators*** are described here in brief terms only. The exact phrasing of the indicators can be looked up from the original indicators or questionnaire items which are listed in Appendix 1. The original indicators can be identified by the ***indicator labels*** shown in the last column of each table.

Table 1.2: Example of the *operationalisation* of a multidimensional concept

Stage 1: The starting point is the development of a *concept* which is the most abstract form of a variable or object of investigation, for example the pre-implementation attitude towards CVRS technology (**"CVRS pre-attitude"** concept).

Stage 2: Depending on the complexity of the concept[29] or the level of detail investigated, the concept is broken down into different components which are commonly referred to as *dimensions* or *sub-dimensions*. In the above example, the **CVRS pre-attitude** concept is split into two dimensions:

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[29] In social or marketing research the term *concept*, as the abstract expression or idea relating to a research object, is frequently referred to by the term *construct* [compare: Shimp and Sharma, 1987; Churchill, 1979; Steers, 1975]. Kerlinger [1970, p. 32] in contrast, indicates a more differentiated view of the two terms: "A construct is a concept. It has the added meaning, however, of having been deliberately and consciously invented or adopted for a special scientific purpose". For convenience, the current research does not differentiate between the meaning of the terms *concept* and *construct* as suggested by Kerlinger, but understands these as synonyms.

- **general CVRS pre-attitude;** and
- **pre-attitude towards the CVRSS's quality relative to the distribution environment.**

Stage 3: Since the latter dimension is complex, it is further split into several sub-dimensions, each of which concerns a specific aspect or element of this dimension: in the above example, the pre-attitude towards CVRS in relation to an organisation's specific requirements in the operational areas of physical distribution such as **transport, warehousing** and (customer) **service**.

In contrast, the non-complex **general CVRS pre-attitude** dimension is not further specified by sub-dimensions; this is indicated by the phrase "not applicable".

Stage 4: Finally, it is necessary to select *indicators* which can be thought of as questions or guidelines for measurement.

In the above example, the dimension **general CVRS pre-attitude** is measured by three indicators or questionnaire items. For convenience, the indicators are described only in brief terms. The exact phrasing of the indicators can be looked up from the original indicators or questionnaire items which are listed in Appendix 1[30]. The original indicators can be identified by the indicator labels shown in the last column of each table. The indicators are listed both alphanumerically and numerically in ascending order. For instance, the indicators beginning with an "A-" are listed before those beginning with a "B-". The indicator *A-188a* precedes the indicator *A-188b*. Equally, the indicator *B-1* is listed before the indicator *B-2*.

As far as the sub-dimensions of the above second dimension are concerned, these are measured by one indicator each.

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[30] See Appendix 1, p. A-1. Note: The survey of the brewing industry was carried out by the use of extensive questionnaires administered to different groups of individuals (see Section 1.4.1.2, p. 15f; in particular Figure 1.1, p. 19). For instance, the questionnaire administered to the managers of the group *CVRS users* alone includes 57 pages. The inclusion of all questionnaires in the current research document would clearly exceed the acceptable size of the document. Therefore, the indicators or questionnaire items are presented in Appendix 1 (p. A-1f) where they are listed in compressed form with an indication of the scales of measurement used.

Multidimensionality

Generally speaking, the use of multiple dimensions and sub-dimensions allows for a more accurate measurement of the concepts under investigation. However, the use of multidimensional concepts also entails the problem of interpreting the importance of individual dimensions and sub-dimensions in relation to the *overall* concept.

The idea of dimensions or sub-dimensions with differing levels of importance in relation to an overall concept is relevant in both *univariate* and *bi-* or *multivariate* analysis. As far as univariate analysis is concerned, this is demonstrated by the following simplified example:

Multidimensionality in univariate analysis: The multidimensional **CVRS user satisfaction** concept concerns the users' satisfaction with several aspects of the technology. The concept may include three dimensions (dimension A, B, C), each of which is measured by one indicator:

- **dimension A** may refer to the general satisfaction with the software.
- **dimension B** may refer to the users' satisfaction with a very specific but extremely important aspect of the software, for example the software's ability to effectively cope with customer time windows or to reduce vehicle mileage.
- **dimension C** also covers the users' satisfaction with a very specific but comparatively less critical aspect of the software, for instance the software's ability to reduce the overtime work of staff in the warehouse or the quality of the software's documentation.

There is obviously good reason to suggest that **dimension B** measures a larger or more important "part" of the overall **CVRS user satisfaction** concept than **dimension C**. In other words, **dimension B** taken individually is a comparatively better measure of **CVRS user satisfaction** than **dimension C**. This is because CVRS technology is predominantly used to improve the quality of routes by coping more effectively with time windows, reducing vehicle mileage, reducing the number of vehicles required etc.

Hence, a user with a high level of satisfaction with **dimension B** but a rather low satisfaction with **dimension C** is likely to have an overall higher **CVRS satisfaction** than a user expressing the opposite; that is, a low satisfaction with **dimension B** and high satisfaction with **dimension C**.

However, of the three dimensions, **dimension A** concerning the general satisfaction with CVRS is considered to be the most important or best individual measure. This is because **dimension A** covers the widest spectrum of **CVRS user satisfaction** and thus also indirectly addresses aspects of **CVRS user satisfaction** not covered by either of the other two dimensions.

Multidimensionality in bi- or multivariate analysis: As far as bi- or multivariate analysis is concerned the above problem is relevant in relation to the significance of associations between dimensions or sub-dimensions. That is, the findings of significant associations between *particularly important* dimensions or sub-dimensions are more meaningful than findings of significant associations between *less important* dimensions or sub-dimensions.

Taking account of the above problem, dimensions and sub-dimensions which are expected to be disproportionally important or good measures of the overall concepts investigated are labelled with a plus ("+") and thus *symbolically* weighted as opposed to *numerically* weighted. This was indicated in the above Table 1.2. The decision as to which dimensions or sub-dimension should be *symbolically* weighted is somewhat arbitrary. It is based on the author's background reading as well as interviews with CVRS suppliers, users and non-users. With a few exceptions the current research deliberately avoids a numerical weighting of dimensions and sub-dimensions. This has been decided because numerical weighting is considered to carry the risk of producing misleading evidence [Schnell et al, 1993].

CVRS models

For procedural and practical reasons, many of the concepts used in the *CVRS models* (presented in Chapters 5 to 7) are operationalised by a single dimension only. Consequently, these one- or unidimensional concepts do not need to be further split up into different components or dimensions. However, with the intention of remaining consistent in the presentation of the concepts' operationalisation process, the unidimensional concepts will be presented in tables including the above categories "concept", "dimension" (or "sub-dimension" as appropriate) and "indicator".

As far as unidimensional concepts are concerned, such as the **school education** concept shown in Table 1.3, the category "dimension" is obsolete; it is, therefore, labelled "not applicable".

Concept	Dimension	Indicator (contents)	Indicator (label)
School education	(not applicable)	Types of schools attended, qualifications obtained	Quali195x

Table 1.3: Example of a unidimensional concept

Similarly, if dimensions of multidimensional concepts are not further specified by sub-dimensions, the associated category "sub-dimension" will remain empty and again is labelled "not applicable". An example is the **general CVRS pre-attitude** dimension shown in Table 1.2.

1.4.2.2 Reliability and validity of measurement

The aim of measurement is to determine values which are as exact and free of systematic and random error as possible [Schnell et al, 1993]. In practice, particularly in relation to abstract research objects, such as intelligence or satisfaction, this aim can only rarely be fully achieved.

To evaluate the quality of measurement instruments, researchers commonly apply two test criteria [Schnell et al, 1993; McDaniel and Gates, 1991; Fink and Kosecoff, 1985; Bailey and Pearson, 1983] which are:

- the ***reliability* of measurement** which refers to the measure's ability to provide consistent results over time; and
- the ***validity* of measurement** which refers to the measure's ability to measure what it was actually intended to measure.

Testing reliability

The *reliability* of measurement can be defined as the square root of the correlation between the observed values and the actual value; the higher the correlation the higher the reliability [Schnell et al, 1993].

There are three general methods to assess the *reliability* of measures:

- ***Test-retest method.*** This assumes that the actual values between measurements at different (two) points in time remain unchanged.

- ***Parallel test method.*** This refers to the ability to produce similar results from using two similar instruments (e.g. a mailed questionnaire survey and a telephone survey) measuring the same object in the same time period; and

- ***Internal consistency testing.*** This refers to the homogeneity of indicators included in a *combined* measure used for evaluating a single concept, dimension or sub-dimension. A *combined* measure can be interpreted as a combination of several equivalent *tests*. This characteristic is referred to as *internal consistency.*

  If the *tests* are understood to be independent repetitions of measurement, it is possible to evaluate the *reliability* of the measure on the basis of its *internal consistency.*

For a number of methodological and, most importantly, practical reasons, the *test-retest method* and the *parallel test method* are rarely applied[31]. Therefore, *reliability* in this research is tested exclusively in terms of *internal consistency* using the *Cronbach Alpha Coefficient*[32].

Testing validity

The forms of *validity* relevant in the current research are:

- ***Face validity.*** This is the weakest form of validity and refers to the degree to which a measurement "looks like" it is measuring what it is supposed to do. It is subjective, since it relies on the judgement of the researcher who designs the measure.

- ***Content validity.*** This refers to the representational adequacy of the content of the measure; that is whether the measure covers all relevant aspects of a concept, dimension or sub-dimension.

- ***Construct validity***

  There are different aspects of *construct validity* [Straub and Carlson, 1989; Shimp and Sharma, 1987; Bagozzi et al, 1979]. The form of *construct validity* relevant in

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[31] For further details see: Schnell et al [1993]; McDaniel and Gates [1991], Churchill, [1979].

[32] Further explained in Section 5.2.2, p. 134.

the current research is commonly referred to as *convergent validity.* It "means that evidence from different sources using different measurements devices all indicate the same or similar meanings of the construct" [McDaniel and Gates, 1991, p. 342]. A similar definition is provided by Churchill [1979, p. 70]: "Evidence of the convergent validity of the measure is provided by the extent to which it correlates highly with other methods designed to measure the same construct."

In questionnaire design using *combined* measures it is common practice to consider the measures' indicators as different measurement devices or methods to evaluate the same research object which may be a concept, dimension or sub-dimension. Hence a combined measure has *convergent validity* if the measure's underlying indicators can be replaced by one another [Schnell et al, 1993]. Messick [1988, p. 51] describes this aspect of validity as "*convergence of indicators*" suggesting that "persons who score high on the test should score high on other presumed indicators of the construct being measured".

Two useful and commonly applied statistical methods for evaluating *construct validity* are ***correlation of items with total scores*** (subsequently referred to as "*total score correlation*") and ***factor analysis*** [Bargl, 1994; Schnell et al, 1993; Messick, 1988; Ives et al, 1983; Kerlinger, 1970].

With the *total score correlation* technique a measure has good *construct validity* if the individual indicators correlate highly with the total scores of the remaining indicators. Using *factor analysis*, a measure has good *construct validity* if the calculation allows for the extraction of as many factors as are predicted by a construct.

The measurement instruments used in the current research are believed to satisfy the criteria of both *face validity* and *content validity.* This claim can generally be supported by the careful and systematic way in which the *structured* interview guides used for the case studies and the self-administered questionnaires used in the surveys were developed.

As to *construct validity*, the quantitative survey data collected in the brewing industry also suggest good results[33].

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[33] See Chapters 6 and 7.

Chapter 2: Basics of VRS

2.1 Introduction

This Chapter presents some background information about VRS focusing on four areas:

- the VRS function in the organisational context;
- the tasks and methods of VRS;
- the flaws of manual VRS;
- the VRS problems in brewery distribution; and
- the basic structure of CVRS.

2.2 VRS in the organisational context

Following Ballou [1978], a meaningful analysis of the impact of CVRS on an organisation requires an understanding of VRS in the context of

- logistics as a *total system*; and
- the *order cycle*.

Logistics is frequently understood to be a corporate service function including various cross-functional activities [Sharman, 1992; Pfohl, 1990; Christopher, 1986; Jansen 1986; Ihde, 1972]. The total logistics system can be divided into three logistical sub-systems [Rupper, 1987; Pfohl, 1990; Maier, 1980]:

- *Procurement Logistics*;
- *Internal Logistics;* and
- *Distribution Logistics* or *Physical Distribution.*

Using this logistics concept as a general framework, the VRS function is part of the *Physical Distribution* sub-system (Figure 2.1).

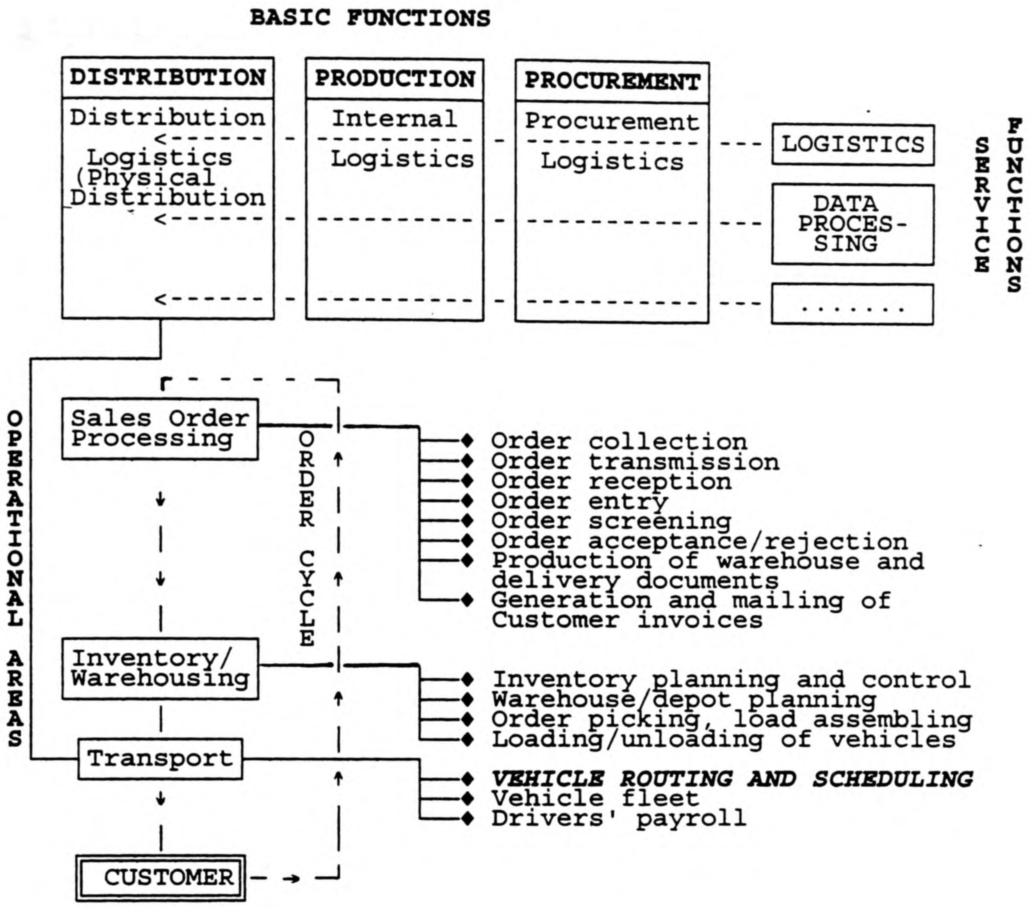

Figure 2.1: VRS in the organisational context

Since the logistical sub-systems are inter-connected, any change in one part of the supply chain can have an impact on another. For instance, a reduction in the order lead time made possible by the use of efficient CVRS could require an adjustment of the *Internal Logistics* and/or *Procurement Logistics* sub-systems. As goods have to be available for delivery at an earlier time of the day, the production output level and the associated supply of raw materials may need to be altered. Alternatively, in the absence of a production facility, an adjustment in the inventory level may be required.

Moreover, each logistical sub-system can be divided into further sub-systems or operational areas. As far as *Physical Distribution* is concerned, these comprise the basic operational areas *Sales Order Processing*, *Inventory/Warehousing* and *Transport* which are also inter-connected. Their combined activities form the *order cycle*. Therefore, any change in the VRS function will inevitably have a direct impact on the activities of the adjacent areas *Sales Order Processing* and *Inventory/Warehousing*. Further indirect impacts will occur within the *Transport* area itself.

2.3 Tasks of VRS

In the route planning literature [Rushton and Oxley, 1989; Siegert, 1988; Candaluppi and Hug, 1986; Bodin et al, 1983; Probol, 1979] and amongst practitioners in physical distribution, the various tasks of VRS are commonly categorised according to their temporal dimensions (Figure 2.2) into:

- long term or **strategic** tasks;
- medium term or **tactical** tasks; and
- short term or **operational** tasks.

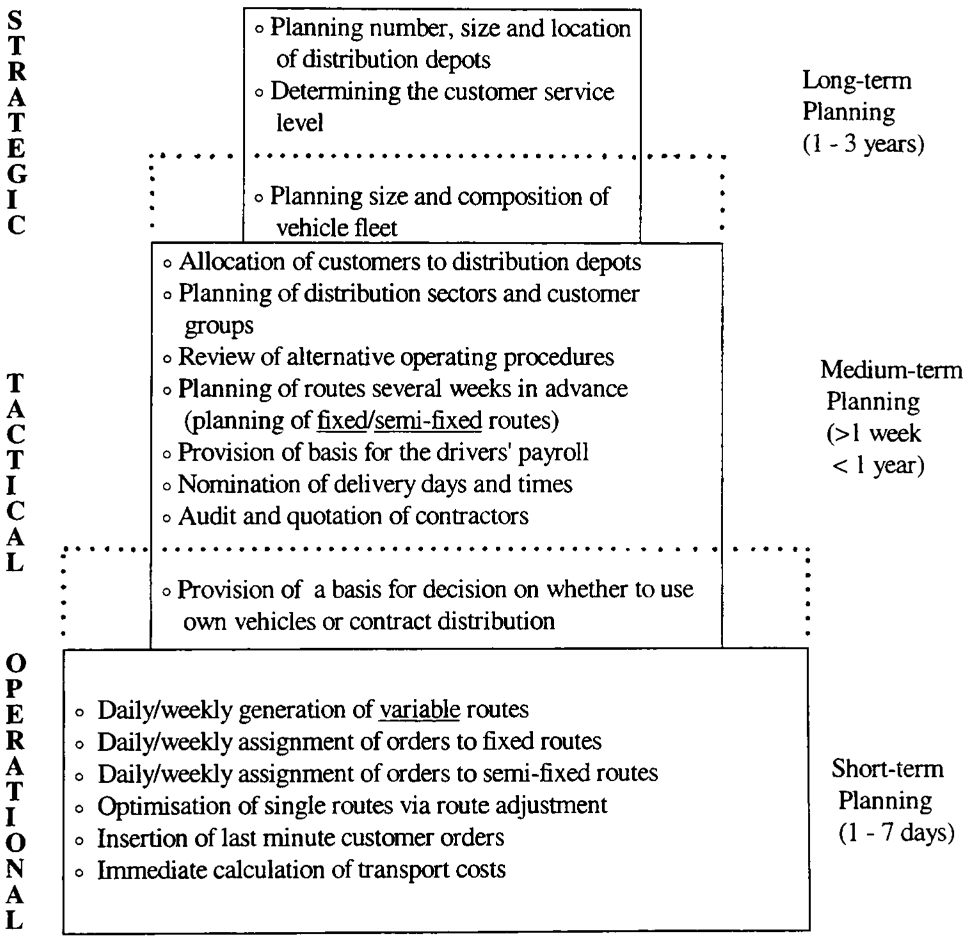

Figure 2.2: Temporal dimensions of vehicle routing and scheduling

The temporal boundaries between the groups are understood to be flexible, especially in view of the close interactions between the decisions involved. Changes in *depot locations* (strategic task) will inevitably require a *reallocation of customers to depots* (tactical task). Similarly a change in the *allocation of customers* to depots may require a *re-adjustment of the size and composition of the vehicle fleet* (strategic task).

Also, organisations have different distribution environments and transport problems which will determine the temporal dimensions of the VRS tasks. Large organisations may carry out certain tasks on a regular basis several times per year, for example *depot location planning* or the *planning of the vehicle fleet size and composition.* In contrast, small organisations with few depots do so in annual or longer intervals.

The terms *fixed*, *semi-fixed* and *variable* routes for VRS are further specified below:

Fixed VRS: In fixed VRS, routes are planned on the basis of historical data for a long period of time, usually for between one and three months. A fixed route lays down a sequence of customers which a vehicle must visit. This VRS approach is applied by companies in, for example, the laundry sector and the supermarket chain segment of the food sector, where customers order mainly fixed quantities of goods on a regular basis. Fixed routes are revised in reaction to fluctuations in demand which are caused by either seasonal trends or changes in the customer base.

At the operational depot level, the daily or weekly assignment of orders to fixed routes is also referred to as the "pigeon hole" system. Each pigeon hole represents a fixed route. The orders relating to a particular service day are posted into their corresponding pigeon hole.

Semi-fixed VRS: Semi-fixed or semi-variable VRS is similar to fixed VRS. Again, orders are pre-allocated to routes, with a general delivery sequence being suggested in advance for each route. However, the allocation criteria are different in that routes are geared towards a greater variability in the order number and quantity per route. This relies on the underlying assumption that customers allocated to a semi-fixed route will order goods on different days of the week. Consequently, the configuration and associated delivery sequence of semi-fixed routes change somewhat from one delivery day to another according to the prevailing customer demand.

This VRS technique is also referred to as the "pigeon hole" system with each pigeon hole representing a semi-fixed route. The spatial relationship between the pigeon holes represent the customer locations' geographical relationships. Again, the orders relating to a particular service day are posted into their corresponding pigeon hole.

Depending on the prevailing number and size of the orders, the semi-fixed routes are adjusted between adjacent pigeon holes. The objective of such route adjustments may be to achieve a high level of vehicle utilisation by weight and reduce vehicle mileage. Alternatively, the routes may be adjusted to spread the daily delivery load over the drivers available. The route adjustment procedure consists of three basic elements:

- Swapping excess weight (orders) between existing adjacent routes; that is, removing orders from overweight routes to adjacent underweight routes.
- Amalgamating underweight adjacent routes.
- Creating new routes which are filled with orders from overweight routes if these orders can not be conveniently removed to existing underweight routes.

A more flexible version of the semi-fixed VRS technique is to cluster large numbers of customers geographically rather than to allocate customers to single routes. Each cluster or group of customers usually represents several routes. Hence, the total VRS problem is split into several easily comprehensible sub-problems. At the operational depot level, routes are generated for each cluster. Again route adjustments can take place between clusters.

This procedure is a compromise between the planning of fully variable and semi-fixed routes. However, since the division of all the customers into sub-groups strongly affects the options available for combining customer orders into sets of routes, this method can be categorised as predominately semi-fixed VRS.

Variable VRS: In fully variable VRS, routes are completely newly planned for each delivery day. Hence, customer orders are not pre-allocated to pre-defined routes or areas. This results in constantly changing route configurations and associated delivery-sequences.

2.4 Flaws of manual VRS

Generally speaking, the flaw of manual VRS is the scheduler's limited "data sorting potential". The scheduler's exploration of many or all delivery options is greatly limited by his or her ability to quickly perform a large number of arithmetical tasks within an acceptably short time [Cooper and Jessop, 1983]. Therefore, manual VRS generally provides sub-optimal solutions, is inaccurate and is prone to human error.

There is no general definition of the complexity of transport problems which can still be handled effectively on a manual basis. In fact, the complexity of transport problems is a function of several factors, for example the number and type of vehicles, the number of orders as well as the number, type and stringency of delivery constraints as well as the geographical size of the distribution area. Some conclusions may be drawn from suggestions given by CVRS suppliers. These generally recommend that an operator should run 10 vehicles or more in order to financially justify the use of CVRS. Similar suggestions have been made by Sussams [1984] who defines the "ideal shape" of the CVRS problem as follows:

- at least 5 vehicles, and preferably more than 20 vehicles per depot;
- five to 20 drops per trip[1]; and
- variable demand.

The commonly used manual VRS system at the depot level is the semi-fixed VRS technique as outlined above. The preference for this planning technique can be explained by its ability to achieve a compromise between the cost efficiency of transport operations and human beings' limited data sorting ability. Nevertheless, the manual VRS technique can be considered inadequate for coping effectively with multiple-drop transport problems involving around 10 vehicles or more.

The typical problems of manual VRS are highlighted by the example of a major UK brewing group where manual VRS is compared with the use of CVRS in an operational role [Eibl et al, 1994].

The brewing group's manual technique previously used for operational VRS was based on semi-fixed routes. Consequently, the manual scheduler built the routes in adherence to a rather rigid work routine. The associated deficiencies can be summarised as follows:

- Overall, the routes were <u>cost-ineffective in terms of vehicle utilisation and mileage</u>.

- Manual VRS was <u>unable to cope effectively with delivery constraints</u>, in particular customer time windows. In fact, due to time pressure, route sequences were determined solely on the basis of the customers' geographical locations. Delivery constraints such as time windows and vehicle access restrictions to customer premises were usually not taken into account.

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1 The term <u>*trip*</u> refers to the daily transport operations made by a single vehicle between leaving the depot and returning to it. One or several <u>*trips*</u> carried out during a single day form a <u>*route*</u>.

- Manual VRS was considered to be time-inefficient, resulting in overtime work, huge amounts of printed and hand written paperwork as well as extreme work pressure. The latter often led to human errors; for instance, omitted sales order notes and errors in arithmetical calculations. This problem was most severe during times of peak demand

- Last but not least, there was insufficient control over transport operations. This was due to the lack of accurate and well documented transport information on important variables such as cost per kilometre and cost per delivered order, exact number of vehicle miles or kilometres per route, precise driving times and working times at customer premises.

2.5 VRS problems in brewery distribution

Road transport operations in brewery distribution can be divided into three general types:

- Primary distribution (transport operations between factories or central warehouses and distribution depots);

- Secondary distribution in the take-home market (transport of goods from depots to supermarkets, off-licence chains and other large retail shops or their warehouses); and

- Secondary distribution in the retail market (transport of goods from depots to tied and free houses, clubs etc.).

The suitability of these VRS problems for standard[2] CVRS technology is evaluated below. The findings are based on the author's background reading[3] and, in particular, evidence obtained from interviews conducted with the suppliers of the software.

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2 Most suppliers customise their software which may well modify the suitability of the software to cope with certain characteristics of VRS problems. Also, some suppliers provide readily available industry-specific versions of their packages. For practical and methodological reasons, however, the effect of customisation and industry specific versions of CVRS packages have not been considered in the following analysis.

3 In particular the CVRS literature presented throughout the thesis. Criteria to classify VRS problems in general have been proposed by Hoya and Graf [1988], Brendel [1987], Bodin et al [1983], Matthäus [1978], Schneider [1978], Joubert [1972] and Webb [1972].

Primary distribution

The standard VRS problems in primary brewery distribution can be sub-divided into two types of VRS problems as follows:

- Firstly, primary brewery distribution may involve straightforward mainly single order operations with vehicles operating between one production unit or central warehouse and several secondary distribution depots. There is generally no need for sophisticated CVRS technology and its investment costs are unlikely to pay off if the software is used exclusively for this type of operation.

- Secondly, primary brewery distribution may involve complex mainly single order operations between several production units or central warehouses and several secondary distribution depots, possibly with routes covering several days. The algorithms of most standard CVRS packages currently available fail to provide practical working solutions for this type of multiple source transport problem.

Secondary distribution in the take-home market

The VRS in the **secondary distribution in the take-home market** (subsequently referred to as "take-home market distribution") involves operations with mainly single or only a few large deliveries or collections. Here the suitability of CVRS tends to be low, but ultimately depends on the complexity of the transport operations.

As mentioned earlier[4] the complexity of VRS problems is determined by factors such as the degree of regularity or irregularity of customer demand, the number of deliveries or collections (subsequently referred to as "orders") to be made per vehicle trip, the number of orders to be considered simultaneously and the stringency of transport constraints such as time windows etc. The lower the complexity of the VRS problems the less is the need for sophisticated CVRS technology and the more difficult it is to justify its investment costs if the software is used exclusively for this type of operation.

For instance, CVRS technology will generally not pay off if used exclusively for vehicle fleets involved in single delivery operations only. Conversely, fleets in excess of 20 to 25 vehicles delivering to three or more customers per trip, perhaps in large geographical distribution areas, may well justify the investment costs of CVRS technology provided

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[4] See Section 2.4, p. 37f.

demand is sufficiently irregular. If demand is completely regular, again, CVRS used in an operational or daily role may not be suitable. Instead, daily orders may be assigned to fixed or semi-fixed routes obtained by strategic-tactical planning.

Secondary distribution of the brewery retail market

CVRS technology can be applied successfully in **secondary distribution of the brewery retail market** (subsequently referred to as "retail distribution"), involving deliveries to pubs, clubs and similar customers. The standard VRS problem in this market involves the use of *multiple-delivery* vehicles (several deliveries including collections of empties) which are *depot-bound*; that is, the vehicles depart from one depot, carry out their deliveries, replace delivered goods with empties as appropriate and return to the original depot. Moreover, demand is sufficiently irregular to justify the generation of variable routes and thus the use of operational CVRS.

The general VRS problem in retail distribution as outlined above can be affected by four special characteristics which tend to constrain the effectiveness of CVRS or which cannot be effectively modelled by most standard CVRS packages:

- Firstly, as far as the loading of small-packaged goods such as cans or bottles is concerned, the maximum amount of goods in terms of weight and/or volume which can be loaded on a single vehicle depends on the composition of the goods. For certain compositions of goods the loading capacities of vehicles may be constrained in terms of tonnage, for other compositions of goods there are constraints in terms of volume. The more diverse the small-packaged goods, the more difficult it is to achieve optimum vehicle utilisation, due to problems of shape and stacking. Ideally, CVRS packages should consider these problems.

- Secondly, certain orders need three-man crews to be unloaded at customer premises. To cope with this problem, most of the CVRS packages currently available transform it into a vehicle-related constraint. Orders requiring three-man crews are then allocated to vehicles manned by one driver and two assistants. Ideally, CVRS packages would handle this constraint flexibly, in that crews (assistants) are treated as separate entities and their allocation to vehicles is considered by the planning algorithm of the software. If this were the case, crews would tend to rotate among vehicles as appropriate thus optimising the available vehicle and human resources.

- Thirdly, brewery retail distribution (or collection of goods) involves certain restrictive work practices. The origins of such work practices are usually union-related. They often have historical links with past working conditions and, therefore, are incompatible with the working standards in today's highly competitive brewing industry. A typical example is the practice of some breweries' crews refusing to carry out more than, for example, two trips per day or route. Under these circumstances, CVRS technology may fail to realise its full potential.

- Fourthly, brewery distribution involves the useboth primary and secondary brewery distribution involves the use of compartmented road tankers. A road tanker generally includes up to eight compartments of different sizes. The generation of routes for tanker operations involves the problem of trading off reduction in vehicle mileage against maximisation of vehicle utilisation. This problem also occurs with respect to the generation of routes for dray vehicles, but it is significantly more severe in relation to road tankers. The main reason for this are the loading restrictions imposed by the number and sizes of compartments available per vehicle. In contrast, dray vehicles can carry far greater varieties of product types which can be loaded anywhere on the vehicle decks.

  A further problem arises from the fact that tanker compartments need to be completely filled, otherwise the vibration of the moving tanker causes the liquids to move in the empty head spaces of the compartments which can adversely affect the quality of the products transported. Moreover, not completely loaded compartments can reduce the load stability. In practice, in particular for longer journeys, compartments are fully filled even if only parts of the loads are actually delivered to customers. The remaining parts of the loads are returned back to the depot or production site where the products are recycled.

  Tankers are predominantly used in primary distribution, while the average secondary distribution depot does not use any tankers at all. For instance, in one major brewing group investigated in this study tankers account for approximately 25% of all primary distribution vehicles. In contrast, only two out of 17 secondary distribution depots use a mixture of tankers and drays with the proportion of tankers representing approximately 10% of all vehicles of those two depot.

  While at the present time the use of compartmented takers is small compared to the use of drays, CVRS packages for use in secondary distribution should ideally be able to consider both types of vehicle. This ability may be of particular importance in the future where legislative and technological change may favour the use of road tankers.

For instance, European health and safety legislation intends to lower the maximum allowable volume of packing containers to be carried manually. This change will reduce the utilisation and, thus, transport productivity of dray vehicles. This may lead to the situation that road tankers which, in Britain, at the present time, are generally more expensive to run than dray vehicles, may become a more frequently used vehicle type.

Further impetus for the increased use of road tankers may arise from the industry's ability and willingness to adopt more advanced technology. For instance, the latest road tankers are computerised and fully automated, facilitating the cleaning of the tankers' compartments, increasing the speed of unloading the products and allowing the number of driving personnel required to be reduced. Equally, latest technological developments have lead to more sophisticated and computer-controlled tank systems for use at customer premises. The new technology allows beer products to be stored in larger quantities and over longer periods.

With the possible exception of the aforementioned four special characteristics, the basic VRS problem in brewery retail distribution as outlined above is similar to the VRS problems in many other sectors of road transport. Typical examples are [Matthäus, 1978; Webb, 1972][5]:

- Deliveries of goods (food and drinks, non-food) in comparatively small consignments from manufacturers and distribution channel intermediaries to retailers;
- Deliveries of goods (industrial parts) in comparatively small consignments from suppliers to manufacturers;
- Deliveries of building material in comparatively small consignments from manufacturers and distribution channel intermediaries to building sites;
- Direct deliveries from mail order companies to private customers (home delivery);

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5 For further detail on the types of VRS problems and their characteristics the interested reader may refer to the excellent book of Golden and Assad [1988] and the working paper of Cooper and Jessop [1983]. Other relevant work on both the practical aspects of transport problems as well as their mathematical and computational foundations may also be found in the list of references presented in Section 1.3.1, p. 5.

- Deliveries of refined petroleum products (e.g. petrol, diesel etc.) from refineries to petrol stations, commercial premises and private homes[6];
- Deliveries and collections of express mail orders;
- Parcel deliveries to organisations and private households;
- Planning routes for booked maintenance services personnel; and
- Collection and return of company employees by buses.

Thus the findings of this thesis may well also be applicable to these areas of road transport.

A VRS problem with virtually opposite characteristics to that of secondary distribution in the brewery retail market or any of the above other sectors is found in the haulage sector. The VRS problem in this sector is frequently *non depot-bound*; that is the starting and ending point of a route or trip are not identical. The customer order pattern is both regular and irregular. Demand also tends to be both deterministic and stochastic; that is only the initial delivery or collection may be known prior to a vehicle's departure for a route or trip. The subsequent customer orders may be received and communicated to the vehicle while it is in operation.

The VRS problem of haulage companies is usually further complicated by the necessity of delivering collected goods onwards (collection onward-deliveries). This is illustrated by the following example:

- A vehicle may start fully loaded from *Depot-1* and deliver the goods to *Customer A* (standard delivery operation from original depot).
- At Customer A the vehicle collects goods which it delivers to *Customer-B* and *-C* (collection onward-delivery).
- At *Customer-C* the vehicle collects further goods to be delivered to *Customer-D* (collection onward-delivery).
- Subsequently the vehicle ends the trip or daily route at *Depot-2* from where it will carry out similar operations. Such deliveries are non *depot-bound*; that is the vehicle starts a new trip or route from a depot other than the original depot.

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6 The VRS problem involving road vehicles in the petroleum industry is similar to the VRS problem of road tankers in the brewing industry.

According to the CVRS suppliers interviewed in this research, most standard CVRS packages are unable to effectively model the constraints involved in *non depot-bound* and/or *collection onward-delivery VRS problems.* At the same time, some suppliers claim to be able to provide specialised or customised versions of their standard software which allow these delivery constraints to be accommodated to a certain extent.

Principal operating parameters

To provide a better understanding of the complexity of road transport distribution in the retail market of the brewing industry the remainder of this section will briefly outline the principal operating parameters involved. These are demonstrated by the example of the average depot of a major British brewing group mentioned previously[7]:

- Orders are collected exclusively by a computerised telesales system; that is, customers are called by the sales departments on fixed days and times of the week. Collected orders are entered directly into the system's database for further processing. Screening of the order then takes place with customer credit checks being made as well as checks on the current availability of stock.
- The order lead time is generally 48 hours which is likely to be reduced to 24 hours in the future. Emergency orders are accepted, if feasible.
- A typical depot operates a secondary distribution fleet comprising between 20 and 25 vehicles. The most commonly used vehicles are heavy goods vehicles (HGVs) with a carrying capacity of 9 to 10 tonnes. Special deliveries are carried out using smaller vehicles, such as vans with a loading capacity of 1.5 tonnes.
- The average depot delivers to between 200 and 250 customers per day. The average delivery quantity per customer is 1.1 tonnes. Most customers receive single deliveries on a weekly basis.
- Multiple-trip routes are common. A typical daily route lasts approximately 9 hours. It covers 150 kilometres (km) on average and can range from 15 km for local deliveries to 300 km or 400 km for long-distance deliveries. Deliveries and returnable collections of empties are carried out together or separately as appropriate.

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7 See Section 2.4, p. 38f.

- Drivers are paid according to a combination of a fixed weekly wage and a bonus based on distance travelled and units delivered.

- Delivery constraints are significant and increasing. The most important are:
  - Narrow customer time windows;
  - Limited access to customer premises;
  - Compact delivery areas with a radius of 200 km per depot on average;
  - One-way streets;
  - Vehicle capacity restrictions due to the delivery of orders with a high weight and/or volume;
  - Many different types of packaging, with the average depot storing 200 or more different products;
  - Unwritten company practices or conventions exist to distribute driver work loads equitably; and
  - A restriction of 9 hours on drivers' maximum daily driving time.

2.6 Basic structure of CVRS technology

The basic structure of CVRS technology is demonstrated by three stages (see following Figure 2.3):

- Data input stage;
- Data processing stage; and
- Data output stage.

Data input stage

The operation of the software starts with the input of data describing a company's internal and external operating or distribution environment. For this purpose CVRS packages usually include *master files* (1). These are supported by *auxiliary files* (2) and *parameter files* (3).

(1) ***Master data files***: These data files can be categorised into six groups including *depot data files, vehicle data files, drivers data files, product data files, customer data files* and *road map data files.*

(2) ***Auxiliary files***: Route planning systems usually incorporate - sometimes at additional charge - *auxiliary files*. These are location data files, also known as gazetteers, and post code data files. They allow the software users to efficiently determine national grid references of their customers' geographical locations using the customers' addresses. Grid references are required by the software in order to determine the exact location of the customers within the road database.

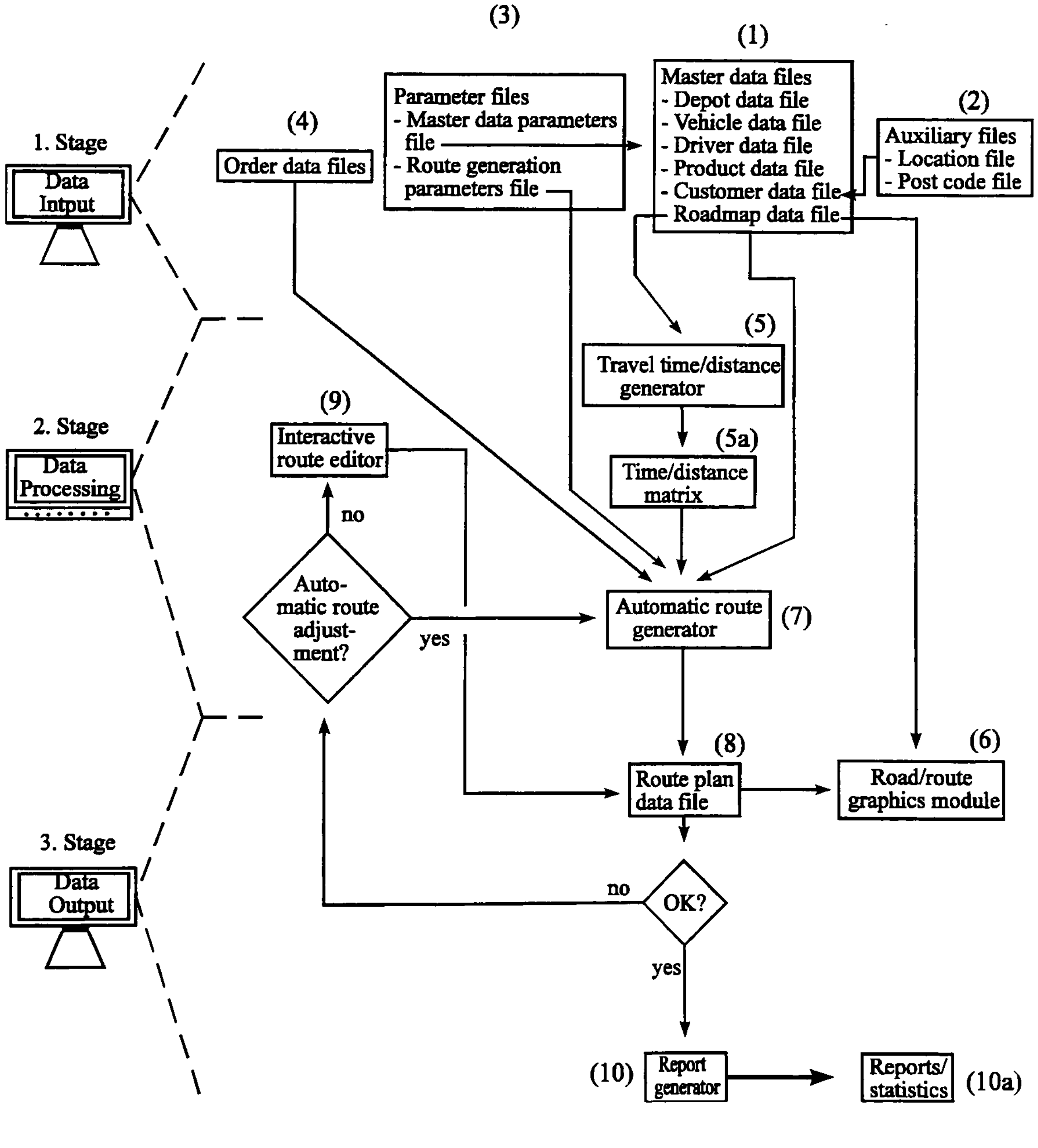

Figure 2.3: Basic structure and operating process of CVRS technology

(3) ***Parameter files***: Generally speaking, the parameters can be categorised into *master data parameters* and *route generation parameters.*

The *master data parameters* control the *master data files.* For instance, the operator may want to limit the maximum number of customers to be included in the customer data files. Should any customer location within the customer master file exceed these limits, a warning message is displayed and/or the customer's acceptance to the data base prevented. It is usually also possible to specify road speeds according to different road categories. Other parameters may allow for the banning of certain road features, e.g. tunnel, ferry or toll, etc.

Using *route generation parameters* the software operator may decide to give priority to certain orders, determine the general shape of routes or restrict the maximum number of orders, maximum mileage etc. per route or trip.

(4) ***Order data file***: The *order data file* includes the daily, weekly or monthly customer orders. Most companies using CVRS in an operational role run a computer-driven order processing system which initially stores customer orders within data files on, for example a mainframe computer. For a particular delivery day customer orders are down-loaded via a data transfer interface from the mainframe computer to the order data file(s) of the CVRSS.

Data processing stage

(5)/(5a) ***Road network generator* and *time/distance matrix***: Within the data processing stage the *travel time/distance generator* usually produces a *travel time/distance matrix* using the road map data stored in the *master data files* (1).

The *time/distance matrix* contains all travel times and distances between customer locations as well as between the customer locations and the location(s) of the operator's distribution depot(s).

(6) ***Road map/route graphics module***: Most route planning packages include a *road map/route graphics module* which displays the road map file on the graphics screen. The road map graphics represent the background against which customers, depots, generated routes and other user-specified information, e.g. speed zones, barriers etc., are displayed. It allows the user to carry out tasks such as:

- plot the road map file (included in the *master data files*);
- examine depot and customer locations in relation to the road map file;
- delete or add customer records from or to an existing road map file;
- delete or add additional road links to the road map file;
- plot the urban areas and speed reduction zones;
- amend the speed code and name of existing road links;
- examine routes or *route plan data files* (8) produced by the *automatic route generator* (7); and
- adjust routes or route plan data files generated by the *automatic route generator* using the interactive *route editor* (9).

(7) ***Automatic route generator***: The *automatic route generator* produces a set of routes (route plan) using data stored in the *master data files* (1), *order data files* (4) and the *time/distance matrix* (5a). This is an automatic process based on the use of complex algorithms which, however, can be controlled by the use of route generation parameters available in the *parameter files* (3).

(8) ***Route plan data file***: This file stores information on each route in terms of delivery sequences, time windows, road links, costs etc. The data are displayed on the screen in the form of tables. Most systems currently available offer a graphical display feature (see above *road map/route graphics module- (6)*) which presents the routes, usually on the underlying road network. On the basis of the route tables or route graphics the operator can either accept the suggested route plan or adjust it as appropriate. This can either be done automatically by repeatedly using the *automatic route generator* (7) or interactively via using the *interactive route editor* (9).

(9) ***Interactive route editor***: All CVRS packages analysed in this research contain some sort of *interactive route editor*. This feature enables the user to adjust manually the initial, automatically generated, route proposals as appropriate using the keyboard or a mouse. The interactively amended route plan can again be examined either in text format or using the *road map/route graphics module* (6). If the route plan in the route plan data file (8) requires further modification, the adjustment procedure is repeated until satisfactory results are obtained.

Data output stage

(10) ***Report generator***: Reports can usually be requested from the *report generator* throughout all phases of the route planning process including the software set-up as well as data validation and evaluation. The *report generator* is most extensively used for the presentation and analysis of the final route results stored in the final *route plan data file* (8).

Most packages allow for the generation of both standard as well as self-defined *reports and statistics* (10a) in both text and graphics formats.

Chapter 3: Success of CVRS

3.1 Past research

Over the past 25 years there have been many attempts to illustrate the practical use and success of CVRS technology. Table 3.1 gives a chronological overview of the existing empirical CVRS studies identified in this research.

The studies typically investigated the use of CVRSSs in distribution operations. It is important to realise that many of these studies concern the evaluation of CVRSSs using actual delivery data of past periods rather than the software's use in live operations. Therefore, some studies suggest potential savings as opposed to actual savings.

Also, the empirical studies identified vary enormously in terms of comprehensiveness and detail. Some studies only briefly outline the CVRSSs used and focus on single aspects or variables of the software's success, for example reductions in vehicle mileage or the vehicle fleet size. Other studies give a more comprehensive coverage of the software and its implementation as well as several tangible and intangible benefits.

As a full presentation of all findings of these studies would go beyond the scope of this research, the following Table 3.1 focuses on the software's tangible benefits identified in each of these studies. The studies are presented by the dates of their publication in reverse chronological order.

Source	Research Object	Results
Eibl et al, 1994	UK based brewery Scottish & Newcastle PLC operates a CVRSS at 15 out of 25 depots.	One depot evaluated reduces annual vehicle mileage by 8% and increases average vehicle utilisation in terms of weight by 11%. The increase in transport productivity allows for a reduction of 2 out of 24 heavy goods vehicles or more than 8% of the total vehicle fleet costs. The system paid for itself with a present net value (PNV) of more than £119,000 within the first year of usage. The accumulated PNV for the system's total life time of 5 years is £298,000.
Bargl, 1994	A sample of 55 German-based companies operating 61 vehicle fleets were investigated via mailed questionnaires.	Reduction of transport costs and costs of the VRS procedure by an average of 9.8% and 35% respectively.
ANON, 1993a	The Italian-based company Salvarani Industry S. p. A. (manufacturer of kitchen components) uses a commercial CVRSS (Optrak).	Savings of 10% over previous manual solution, reduction in carrier costs by 5%, reduction of scheduling period by 83% from 12 to 2 hours.
ANON, 1993b; Meall, 1993	UK Post Office uses a commercial CVRSS (Trandos).	Reduction of vehicles and vehicle mileage by up to 20% depending on area of software's usage.
Canen and Piz-zolato, 1993	Subsidiary of a large Brazilian multinational corporation tests a CVRSS for distribution in a major customer area from a single warehouse.	Achieved reduction of 5.5% in travel distance and 4.9% in travel time.
Davis, 1993	PepsiCo De Mexico - a joint venture of Pepsi-Cola International and the Protexa Group - implements a commercial CVRSS (Roadshow).	The software allows for a significant improvement of the efficiency of transport operations.
Aubin, 1992	Canadian-based public agency Urgences Santé (responsible for co-ordinating ambulances in the Montréal area) uses a PC-based scheduling system based on linear programming and a branch-and-bound algorithm.	Annual saving of approximately $250,000.
Bowman, 1992	USA-based company Simmons Co. implements a commercial CVRSS (Trucks) which allows for a new way of supplying the customers.	Under its Make-To-Order program, Simmons has virtually eliminated the warehousing of products. It can fill an order straight off the production line in 4 to 5 days.
	USA-based company Emery Waterhouse implements commercial CVRS (Trucks).	Savings of 300,000 miles a year.
Erkut and MacLean 1992	Alberta's (Canada) largest food distributor Scott National with 7 depots implements changes proposed by a computerised vehicle routing and scheduling system.	Savings of approximately 10% on annual fuel costs.
Murray, 1992	Unnamed company in manufacturing industry tests a commercial CVRSS (Paragon2) for deliveries and collection of mainly 800 urban based customers on daily basis using 32 car derived vans.	Proposed savings - vehicles: 6% to 59% - work time: 12% to 49%

Table 3.1: Tangible benefits of CVRSSs evaluated in past research

Source	Research Object	Results
Parkin, 1992	Unnamed multinational manufacturing company with one factory, one major depot and five smaller regional depots in the UK tests a commercial CVRSS on the basis of one week's orders.	Proposed savings of vehicles by 10% - 30%.
van Vliet et al, 1992	Major Netherlands-based food co-operative Suiker Unie implements a commercial CVRS package (SHORTREC) to solve its operational multi-depot vehicle-routing problem with time windows.	Since implementation in September 1991 Suiker Unie achieved about 7% savings in operating costs.
Wunder-lich et al, 1992	Southern California Gas Co. (SOCAL) initiated a study in 1988 to examine the potential benefits of using a commercial CVRS package to route and schedule its meter readers. SOCAL tested and evaluated this software in a carefully chosen sample region representing about 2.5% of the SOCAL service area.	Proposed potential savings of about $874,185 a year. The figures are conservative; a full implementation with graphics and manual commands would further improve the situation.
Bodin et al, 1989	The town of Oyster Bay, New York, USA, uses a self-developed CVRSS for the operation of solid waste collection vehicles.	Reduction of 8% or 3 out of 40 vehicles giving rise to savings of $200,000 p. a..
Holmes, 1989	Unnamed company in the food industry uses a commercial CVRSS (Paragon) for strategic, tactical and operational planning.	Savings of £200,000 p.a. from rationalising the depot structure. Further savings £500,000 p. a. or 20% of total costs from improved secondary distribution to customers.
	Unnamed company in the oil industry uses a commercial CVRS (Paragon).	Savings are estimated to be £13 million or 10% of the total distribution costs.
Holt and Watts, 1988	Australian-based unnamed companies in the newspaper industry use self-developed VRS software for the distribution of goods.	1) One company reduces vehicles by 14% from 35 to 30 vehicles. 2) Another company reduces vehicles by 26% from 19 to 14 vehicles. Also savings of one daily route and 8% in vehicle mileage.
Brown et al, 1987	USA-based Mobil Oil Corporation adopts real-time computer system for centralised control of distribution to customers: 600,000 customer orders p.a. serviced via 120 bulk terminals and more than 430 vehicles.	Annual savings of about $3,000,000 in operating expenses associated with delivering light products.
Sculli et al, 1987	The Hong Kong-based New Territories Service Department responsible for refuse collection activities tests several computer-based algorithms to improve work practices.	Using average figures relating to the refuse volume over a past period of time, the computer-simulation proposes potential savings of the order of 8%.
Fehr and Fontaine, 1987	Unnamed company in food industry uses a commercial CVRS package (VSPX) at a distribution site for the daily delivery of fruit and vegetables to 100 customers.	One site reduces the daily VRS period by 91% from 12 hours to less than 1 hour.
	Unnamed company in food industry uses a commercial CVRSS (Intertour) for the delivery of bread and pastry to a total of 700 customers located within a radius of 50 km.	Reduction of routes by 12.5% from 40 - 35. Reduction of 25% in km travelled.

Table 3.1 (continued): Tangible benefits of CVRSSs evaluated in past research

Source	Research Object	Results
Fehr and Fontaine, 1987	Unnamed company in food industry uses a commercial CVRSS (Multitour) for the delivery of a) dairy products and b) frozen food to 360 customers.	a) Distribution of dairy products: reduction of 16% in km travelled per tonne delivered; reduction of 19% in travel time per tonne delivered. b) Distribution of frozen products: reduction of 2% in total km travelled; reduction of 6% in km travelled per tonne delivered, reduction of 6.7% in travel time per tonne delivered.
	Unnamed company in food industry uses commercial CVRSS (Pragma) for the delivery of various food stuff to 450 customers with 48 vehicles.	Increase in vehicle utilisation by weight of 22% from 7.9 tonnes to 9.6 tonnes. Reduction of costs by 8%. Reduction of km per tonne delivered by 20% from 25 km to 20 km.
Golden and Wasil 1987	Unnamed beverage distributor uses a CVRSS. Coca Cola bottler in Europe uses a CVRSS.	Company does not require additional vehicles, despite sales increase of 30%. Reduction of total delivery costs by 10% to 20% in the short-medium haul metropolitan area and 3% to 13% in the medium-long-haul rural area.
Guise, 1987	Unnamed UK based brewery uses a commercial CVRSS (Dayload).	Potential reductions of 3 drivers. Also, potential reduction of vehicle fleet by 14% or 3 out of 22 vehicles.
Peters and Doganis, 1987	Unnamed company (manufacturing and distribution of packaged food) with 6 depots uses a commercial CVRS system (1974: Routemaster) for strategic and tactical planning.	By saving £300,000 the system paid for itself in the first 2 years.
	Unnamed third party distributor offering warehousing and consolidating delivery services evaluates several commercial CVRSSs (Dayload, Loadstar and Mover).	The evaluation suggests potential reduction of 10% in delivery costs.
	Unnamed company in the pharmaceutical industry evaluates a commercial CVRSS (1984: Paragon).	The evaluation suggests a potential reduction of the vehicle fleet by 15% or 50 out of 340 vehicles.
Canda-luppi and Hug, 1986	Unnamed company in pharmaceutical industry operates a commercial CVRSS for delivery to 800 customers in 240 towns from a central warehouse with 30 vehicles.	Reduction in the vehicle fleet size by 16% from initially 30 vehicles to 25 vehicles.
Eastburn and Chris-tensen, 1986	UK supermarket group Argyll Stores uses a commercial CVRSS (Paragon) at a distribution centre.	Reduction in the vehicle fleet of 39% or 15 out of 38 vehicles; this, despite a volume increase of some 20% over the same period. Subsequent software installations at two further distribution centres allow for a 30% reduction in driver hours.
Waters, 1986	A set of computer-based VRS algorithms is tested in Community nurse travelling (West of Scotland Health Board, UK).	Proposed reduction of 7% to 30% in total distance travelled equalling variable cost savings of £8,736 - £37,440.
	A set of computer-based VRS algorithms is tested in an UK based company John Hamilton (Pharmaceutical) Ltd.	Proposed reduction of 10% in vehicle mileage and saving of one vehicle equalling £12,500 p. a..

Table 3.1 (continued): Tangible benefits of CVRSSs evaluated in past research

Source	Research Object	Results
Waters, 1986	A set of computer-based VRS algorithms is tested in an UK based subsidiary of US company Burroughs Corporation (machine manufacturing).	Proposed cost savings of \$80,000 to \$160,000 from the re-location of depots.
Belardo et al, 1985	USA based Southland Corporation (world's largest operator and franchiser of convenience stores) uses a geographic based CVRSS at one out of four distribution centres.	Saving of one daily route out of 35, equalling savings of \$1,000 per day.
Bocxe and Tilanus, 1985	Dutch company NMV-Campina (dairy industry) tests several CVRSSs for use in the collection of milk.	Overall, the CVRSSs do not lead to cost savings which would justify an investment in this technology. The systems do not meet the company's requirements and are abandoned.
Evans and Nor-back, 1985	The USA based company Kraft Inc. (food industry) tests a self-developed CVRSS for daily deliveries of up to 250 customers using 10 days of actual delivery data from one of its largest distribution regions.	Proposed savings of 10.7% in overall costs excluding potential savings of fixed costs. Prospects of reducing the variable costs by further 3% to 5%. Further savings of fixed costs are also expected.
Sus-sams, 1984	Unnamed company uses a CVRSS.	Cost savings of 7% to17% depending on the efficiency of the load planners at each of the company's depots.
Herlihy et al, 1984	Unnamed German-based company in dairy industry uses a CVRSS for the collection of milk.	Reduction of 2.5% in vehicle mileage.
Waters, 1984	UK wholesaler operating from a single warehouse uses a CVRSS for serving 163 customers in the city boundary of Glasgow.	Savings of about 10% in vehicle mileage or £2000 p.a.: reduction of 9% or 1 out of 11 vehicles; release of one driver for other work.
Zielinski, 1984	USA based Edward Don Company (distribution of food service equipment and supplies of restaurants, schools, hospitals and other institutions) implements a commercial CVRSS (ROVER) at its Chicago depot which delivers to 20,000 customers located over a 12,000 square mile area.	Increase of 10% in orders per vehicle with unchanged vehicle mileage, resulting in a decrease of 10% in miles per stop. Increase of 7% in stops per hour. Reduction of 8% in vehicle fleet size and 7% in costs per order.
Bell et al, 1983	Air Products and Chemicals Inc. uses a CVRSS at one distribution site for the distribution of industrial gases.	The average mileage per gallon delivered decreased by 9.1%. Savings in total mileage of 10.4%. The increase in tanker productivity reduces future requirement to purchase additional vehicles to meet growing business needs; estimated savings of capital expenditure of \$445,000 annually. Average savings from the CVRSS at the firm's 16 depots is estimated 6% to 7.5% or \$1.54 million - \$1.72 million p. a.
Stacey, 1983	UK based unnamed company investigates the benefits of a commercial CVRSS (VAN-PLAN) for use at its 30 delivery depots each with between 100 and 400 daily orders.	Proposed savings from 5% to 6.3% per depot.

Table 3.1 (continued): Tangible benefits of CVRSSs evaluated in past research

Source	Research Object	Results
Fisher et al, 1982	USA based company Du Pont Inc. (chemical, medical equipment industry) uses a commercial CVRSS (ROVER) for the delivery of a medical machine of the size of photocopier to 1,500 customers (50 routes) in 1,000 cities.	Reduction in delivery costs by approximately 15% on US territory. Further 10% delivery costs savings expected for the delivery of the machine in Europe.
Brown and Graves, 1981	USA based company Chevron (distribution of petroleum) uses a CVRSS for the dispatch of a fleet exceeding 300 vehicles and 2,600 orders per day.	Reduction of distribution costs by about 3%.
Christo-fides, 1981	Unnamed company in the chemical industry operating 12 compartment vehicles evaluates a CVRSS.	Proposed savings of 12% to 30% of existing vehicle fleet.
Roth-haar, 1980	German-based brewery Parkbrauerei AG uses a commercial CVRSS (TRAFIC) at a depot which delivers to between 90 and 220 customers daily.	Savings of 2.5 to 3.5 minutes delivery time per hectolitre beer delivered.
Mowat, 1978	UK based company Schweppes (beverage industry) appraises several CVRSSs.	The best system proposes a reduction of 4% in travel times and distances.
Foulds et al, 1977	New Zealand Manawatu Co-operative Dairy Company tests three computer-based standard routing algorithms at a depot with 51 tankers.	The evaluation indicates potential savings of 5% to 6% in vehicle mileage.

Table 3.1 (continued): Tangible benefits of CVRSSs evaluated in past research

As can be seen from the above table, the existing empirical studies cover single or small numbers of CVRS applications in individual sectors of commerce. Many of the studies are excellent research projects taken on their own. However, with a view to a *long-term multi-person research effort* [Kubicek, 1975a] which aims to analyse, systematise, and consolidate research findings from previous studies and thus supply a consistent and empirically founded body of research, the studies are deficient in the following areas:

a) Absence of a common research framework

Most empirical CVRS studies identified in this research have been established in isolation. With perhaps the exception of Bargl's [1994] recent empirical work, no attempt has been made to synthesise the existing research material on CVRS and carry out a large scale research project involving several organisations or fleet operators using CVRS technology. Ideally, CVRS research should be conducted within a theoretical research framework to integrate and compare all existing empirical studies [Kubicek, 1975a]. Such a framework needs to be based on a common research methodology and, perhaps most importantly, the use of common research variables.

The reality of CVRS research, however, speaks a different language. Most of the empirical research is qualitative in nature. Such qualitative or case study research is typically preoccupied with collecting high quality and rich data which allow for in-depth conclusions on the particular objects of analysis.

Much of the research has ignored the need to focus on commonly used key variables or dimensions or, if particular or new variables are investigated, to define these precisely. For instance, some studies have investigated the success of CVRS in terms of reductions in mileage, vehicles, travelling time and/or number of routes. Other studies have analysed the software with regard to savings in costs, time and mileage per tonne or order delivered.

Also, some studies use different terms for apparently the same or similar variables, for example, (financial) savings [Bell et al, 1983; Stacey, 1983], overall costs [Evans and Norback, 1985] and total delivery costs [Golden and Wasil, 1987]. Unfortunately, only a few studies supply clear definitions of what cost elements are covered by these variables.

b) Different operating environments

Each sector of commerce has certain special characteristics (and thus special requirements) in CVRS. Overall meaningful empirical findings, which allow for generalisation of the events described, need to be obtained from cases within the same operating environments or sectors of commerce. However, the existing empirical research covers CVRS applications in various operating environments. Consequently, even if the current empirical research material and findings actually were comparable (or were made so by, for example abstraction of general success factors), this would not necessarily allow for the generalisation of the conclusions obtained.

c) Biased presentation of CVRS applications

The great majority of empirical studies on the use of CVRSSs tell of success stories. However, the evidence of the current research suggests that some CVRS applications are or were unsuccessful: they either produce unsatisfactory results or, in extreme cases, were abandoned. Ideally, a study aiming to provide generally valid findings on the use and success of CVRS applications needs to be based on all applications (consensus survey) or a statistical sample of all applications within a homogeneous environment, for example, a particular industry.

d) Limited research variables

Many of the existing studies have investigated the success of CVRSSs by one or a limited number of evaluation criteria or variables as outlined above. The limited approach to evaluation bears the risk of giving an incomplete picture of CVRS technology's full impact on an organisation. Ideally, CVRS success should be investigated by the use of a multidimensional measure.

Need for a new empirical study

The above analysis has highlighted the constraints on synthesising the existing empirical research on the benefits or success of CVRS (here referred to as "**CVRS success**"). A first step towards solving the existing research dilemma has been made by the recent work of Bargl [1994]. In a survey via mailed questionnaires he provided statistical evidence that CVRS used in an operational role is an effective means of reducing costs in physical distribution. The findings are based on a sample of 55 companies operating 61 vehicle fleets in various sectors of the German road transport industry.

However, further large-scale and in-depth research, ideally combining both qualitative and quantitative research methods, is required to give empirically founded insight into the various components of CVRS success. Such a study should investigate the components of success to be gained from using CVRS at all levels of transport planning including strategic-tactical and operational issues. It is the intent of this research to provide such a study.

3.2 Measuring CVRS success

The rather limited approaches in past empirical research to the measurement of **CVRS success** are considered insufficient and inaccurate for the current research. Following Sanders [1984] the current research evaluates **CVRS success** by a multi-dimensional measure. The measure is composed of a *micro level* relating to **user satisfaction** and a *macro level* relating to **organisational efficiency** as illustrated in Figure 3.1 overleaf.

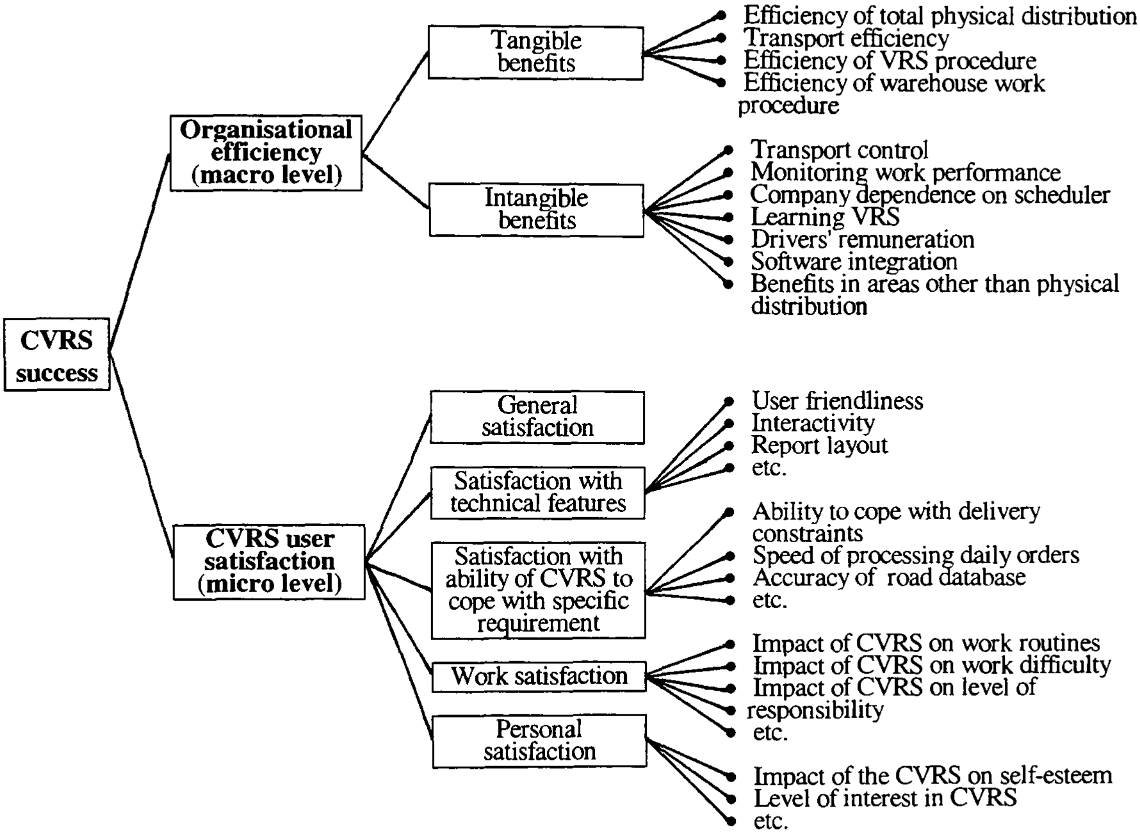

Figure 3.1: Multi-dimensional measure of CVRS success

3.3 Success of CVRS in the brewing industry

The empirical research on the success of CVRS technology as discussed above gives reason to suggest the following hypothesis:

***Hypothesis 1*:** CVRS systems used in both a strategic-tactical and in an operational role are successful in increasing organisational efficiency and individuals' satisfaction in the brewing industry.

Evidence:

The data provided by the case studies and the survey of this study strongly support *hypothesis 1*.

Regarding the success of strategic-tactical CVRS, evidence is available predominantly from case studies of five breweries. The information was supplied by the breweries' management service, logistics or similar technical planning functions.

As far as success in operational CVRS is concerned, the survey's findings are based on responses from questionnaires returned by 39 operational distribution sites. The depots are run by 12 *independent operating centres* with *CVRS decision-making authority*[1]. The actual number of responses varies according to the individual items or variables measured in the questionnaire. The sites are distribution depots located at the production facilities of breweries and, in the case of larger breweries, external distribution depots. For instance, Brewery-A has six, Brewery-B eleven and Brewery-C twelve external depots participating in the survey. Each distribution site is treated as a single respondent.

Section 3.3.1 measures the *macro level* of **CVRS success**, including the **tangible benefits** concept and **intangible benefits** concept in strategic-tactical CVRS. Section 3.3.2 measures the same dimensions in operational CVRS. Section 3.3.3 measures the *micro level* of **CVRS success** in general, being specified by the **CVRS user satisfaction** concept.

3.3.1 Organisational efficiency in strategic-tactical CVRS

3.3.1.1 Measurement of variables

Operationalisation of concepts

The operationalisation of the **organisational efficiency** concept in strategic-tactical CVRS is shown in Table 3.2.

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1 See Section 1.4.1.1 ("Case studies"), p. 12f; see also Section 1.4.1.2 ("Survey of current, potential and past users of CVRS in the brewing industry"), p. 17f.

Concept	Dimension	Sub-dimension	Indicator
Orga-nisatio-nal efficien-cy	Tangible benefits	Efficiency of physical distribution	Impact of CVRS on distribution costs including costs for vehicles, drivers and warehouses
		Efficiency of VRS procedure	Reduction in the VRS period
	Intangible benefits	*	*

* Intangible benefits are also expected to arise from CVRS used in a strategic-tactical role. However, they will not be discussed in further detail, as they are broadly similar to the intangible benefits in operational CVRS presented in Section 3.3.2.

Table 3.2: Operationalisation of the *organisational efficiency* concept in strategic-tactical CVRS

Selection of scales

The **impact of CVRS on distribution costs** indicator is based on a ratio scale. The **reduction in VRS period** indicator is measured on an ordinal scale consisting of the three categories "significant", "little" and "not at all".

Special attention needs to be given to the problems involved in accurately measuring the impact of strategic-tactical CVRS on an organisation's overall distribution costs including costs for vehicles, drivers and inventory/warehousing. Generally speaking, this problem is inherent to the nature of strategic-tactical planning itself. Measuring, for instance, the cost implications arising from the reallocation of customers to depots or a change in the vehicle fleet mix, requires comparing the total distribution costs before and after the changes have been carried out. However, in the period between the changes being made and the evaluation of the savings being carried out, the distribution environment constantly changes; that is, many related variables cannot be kept simultaneously constant. For example, new material handling and transport technology may become available. Customers' drinking behaviour may also change which affects the retailers' ordering patterns in terms of delivery frequency as well as the quantity and types of goods required. Moreover, new safety regulations for workers and equipment may be introduced.

Therefore, a comparison of costs at two points in time is unable to provide accurate evidence of the CVRS technology's benefits. Also, financial implications or the *decision* *relevant* costs[2] [Riebel, 1977] arising from strategic-tactical changes such as the reallocation of customers to depots are complex; that is, they occur in both primary and secondary distribution and include capital investment in stock, material handling and administration at each depot. Finally, it is difficult to measure which extra savings arise from decision-making using CVRS compared with manual planning. The evaluation of cost savings would require comparing average cost savings obtained from strategic-tactical CVRS conducted manually in the years prior to the software's installation with average cost savings achieved after the software's implementation.

As a result of the above methodological problem of measurement, the cost savings arising from strategic-tactical CVRS evaluated in the current research are based on the respondents' estimates.

Because of the small number of only 6 *independent operating centres* using strategic-tactical CVRS technology, the responses are analysed exclusively by univariate statistics using frequency counts.

3.3.1.2 Results

Overall, the intangible benefits in strategic-tactical CVRS are similar to those in operational CVRS which are presented in section 3.3.2. Therefore, the following sections on strategic-tactical CVRS will focus on the tangible benefits only.

3.3.1.2.1 Efficiency of physical distribution

Strategic-tactical CVRS has been shown to offer a range of options for finding answers to so called "what-if" problems. Such simulations enable the system operators to change a single distribution parameter at a time and thus measure the resulting impacts of the enacted change in terms of distribution costs, customer service level etc. Regarding, for example, the allocation of customers to depots, CVRS accommodates the simulation of a

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[2] *Decision relevant* or *entscheidungsrelevante Kosten* "(...) lassen sich vielmehr nur fallweise für jeweils ganz bestimmte Maßnahmen or Maßnahmenbündel - und zwar abhängig von der jeweils gegebenen Situation - ermitteln" [Riebel, 1977, p. 28]. Translation: Decision-relevant costs are to be evaluated only in relation to certain measures or a package of measures - and this for a certain given situation.

much larger number of distribution scenarios. Also the software allows for the consideration of a greater number of delivery constraints, for example, legal regulations (max. loading weight, driving times etc.), customer time windows, access restrictions to customer premises and road speeds. Therefore, the planning results are considerably more precise and valid than those accomplished by manual VRS. Improved planning results are also achieved in relation to other strategic-tactical planning tasks, e.g. the allocation of delivery days and times to customers or the allocation of customers to fixed and semi-fixed routes or areas.

Despite the methodological problems of measurement, Brewery-A, Brewery-B, Brewery-C, Brewery-G and Brewery-I have made minimum estimates of the average annual distribution cost savings achieved by the use of their CVRS system in a strategic-tactical role. These range from 4% to 10% of the total annual distribution costs, including costs of vehicles, drivers and inventory/warehousing (Table 3.3). The actual savings vary depending on the strategic-tactical changes made in each year of the software's usage. The breweries have reported instances where the computerised reallocation of customers between depots and the optimisation of allocated delivery days have led to savings of up to 20% of the vehicle fleet and the associated driving personnel. Similar savings were achieved in terms of vehicle mileage.

Distribution site	CVRSS used (Date of installation)	Distribution cost savings achieved from CVRS p. a.
Brewery-A	DiPS (1983)	5% - 9%
Brewery-B	Routemaster (1982)	4% - 8%
Brewery-C	Routemaster (1983)	5% - 9%
Brewery-D	DiPS (1979)	No estimate available, as CVRS is used on an irregular basis
Brewery-G	DiPS (1992)	5% - 10%
Brewery-I	Paragon2 (1991)	5% - 10%

Table 3.3: Distribution cost savings in strategic-tactical CVRS

3.3.1.2.2 Efficiency of CVRS procedure

In all the cases analysed, the use of CVRS led to an increase in the efficiency of the VRS procedure by facilitating a significant reduction in the planning period for each strategic-tactical planning scenario performed. Prior to automation, strategic-tactical VRS was carried out at irregular time intervals, whenever such planning became necessary. Such "necessary" situations may have occurred as a result of depots closing or additional breweries and their attached depots being acquired. As CVRS is more time-efficient, the users have been able to carry out a greater number of projects. In the case of Brewery-I, for instance, the use of strategic-tactical CVRS has turned into a regular activity carried out by its central management service department.

3.3.1.2.3 Pay-back period

The pay-back period of strategic-tactical CVRS can be extremely short, particularly in large organisations with several depots and large vehicle fleets, as demonstrated by the example of Brewery-A. Calculating the minimum saving of 5% on the basis of the brewery's distribution costs including costs of vehicles, drivers and warehousing at the time of the software's implementation, this amounted to annual savings of at least £1.2 million. Comparing these savings with the system's total investment costs[3] (including costs of the software, implementation and training) of less than £20,000 at historical prices the *DiPS* package paid for itself after less than one year of use [Eibl et al, 1994].

3.3.2 Organisational efficiency in operational CVRS

3.3.2.1 Measurement of variables

Operationalisation of concepts

The following Table 3.4 shows the operationalisation of the **organisational efficiency** concept in operational or daily CVRS[4].

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[3] The calculation ignores personnel costs for the operator of the CVRSS (below referred to as "CVRS operator"). The reason is that these costs are not *decision relevant*; that is, they do not occur as a result of the decision to use the software, because the software is usually operated by personnel who used to carry out manual VRS prior to automation.

[4] The exact phrasing of the concept's indicators can be looked up from the original questionnaire items in Appendix 1 (p. A-1f). The label of each indicator is shown in the table's last column.

Concept	Dimension	Sub-dimension	Indicator (contents)	Indicator (label)
Organisational efficiency	Tangible benefits	+ Transport efficiency A	Reduction in fleet size by vehicles	W-185
		+ Transport efficiency B	Reduction in fleet size by vehicles as a percentage of previous number of vehicles	W-186
		+ Transport efficiency C	Reduction in vehicle mileage	W-182
		+ Transport efficiency D	Increase in vehicle utilisation by weight/volume	W-183
		+ Transport efficiency E	Increase in vehicle utilisation by time	W-184
		+ Transport efficiency F	Reduction in drivers' overtime work	A-188a
		+ Efficiency of VRS A	Reduction in VRS period in man-hours	W-180
		+ Efficiency of VRS B	Reduction in VRS period in man-hours as percentage of previous man-hours	W-181
		Efficiency of warehouse work procedure	Reduction in warehouse staff's overtime work	A-188n
Organisational efficiency	Intangible benefits	+ Efficiency of VRS A	Coping with delivery constraints	A-188i
		+ Efficiency of VRS B	More comprehensive planning options	A-188b
		+ Efficiency of VRS C	Increase in consistency of planning results	A-188c
		+ Efficiency of VRS D	Reduced occurrence of human errors	A-188g
		Efficiency of VRS E	Significant reduction in paper work	A-188d
		+ Efficiency of VRS F	Increased time to do work more effectively	A-188o
		+ Efficiency of VRS G	Improved compliance with legal regulations	A-188h
		+ Transport control A	Improved control over the transport operation	A-188r
		+ Transport control B	Cost control by comparing 'planned' - 'actual' costs	A-189d
		+ Transport control C	Improved statistical analysis of distribution data	A-188u
		+ Transport control D	Improved transparency and awareness of costs	A-188v
		Monitoring work performance A	Improved monitoring of vehicle schedulers' working performance	A-188s
		+ Monitoring work performance B	Improved monitoring of drivers' working hours	A-188t
		+ Dependence	Decreased dependence on the scheduler	A-188p
		+ Learning VRS	Reduced time period for learning job of VRS	A-188q
		Drivers' work load	More equal spreading of work over drivers	A-189g
		Warehousing	Smoother work procedures in the warehouse	A-188m
		+ Software integration	Reduced duplication of data entry and thus reduced errors	A-188l
		+ Sales & Marketing A	Improved customer service	A-189a
		+ Sales & Marketing B	Increased potential for acquisition of customers	A-189b
		Sales & Marketing C	Extended period of order collection/acceptance	A-188j
		Sales & Marketing D	Improved coping with emergency orders	A-188k
		Sales & Marketing E	Improved negotiation of customer service level	A-189c
		Sales & Marketing F	Improved customer assessment with cost	A-189e
		+ Finance	Improved transport information for drivers' pay	A-189h

Table 3.4: Operationalisation of the *organisational efficiency* concept in operational CVRS

As outlined earlier, the use of multidimensional measures usually requires weighting of dimensions and sub-dimensions which are expected to be disproportionally important or good measures of the overall concepts investigated. The weighting is here carried out *symbolically* as opposed to *numerically*[5]; that is, sub-dimensions which are assumed to be of higher importance than others are labelled "+".

Selection of scales

Tangible benefits

The indicators **reductions in the VRS period** (W-180, -181) and **reductions in fleet size by vehicles** (W-185, -186) are based on a ratio scale.

The indicators **reductions in the vehicle mileage** (W-182) and **improvements in vehicle utilisation** (W-183, -184) are based on a nominal scale. The scale has two categories, dividing the respondents into two sub-groups according to whether or not the software led to savings in vehicle mileage. The use of such a scale is necessary because some of the distribution sites investigated were unable to accurately quantify the vehicle mileage saved as a direct result of using CVRS.

The indicators **reduction in overtime work of drivers** (A-188a) and **reduction in overtime of warehouse staff** (A-188n) are based on a *Likert type five-point ordinal scale* (below referred to as "*Likert type five-point scale*"). Each variable or questionnaire item consisted of a statement concerning a particular benefit. The respondents specified to what extent each benefit applied to their organisations' use of the CVRSSs by ticking one out of five categories. Each category accounts for a score as follows:

1 point: the benefit occurred "not at all";

2 points: the benefit occurred "little";

3 points: the benefit occurred "somewhat";

4 points: the benefit occurred "strongly"; and

5 points: the benefit occurred "very strongly".

An additional "don't know" category was available for respondents to indicate their inability or unwillingness to answer any particular items.

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5 See Section 1.4.2.1 ("Multidimensionality"), p. 28f.

Intangible benefits

All indicators relating to intangible benefits are based on the *Likert type five-point scale* outlined above.

The evaluation of *decision relevant*[6] costs and benefits involved in operational CVRS at single distribution sites is a substantially easier procedure than in strategic-tactical CVRS. In most instances, changes in human and material resources can be attributed directly to the use of the software, even though one still faces the problem of comparing costs or, more generally speaking, situations at two points in time while the distribution environment is dynamic. Nevertheless, considering the idea of *decision relevant costs*, it is necessary to eliminate the impact of possible "external" factors when evaluating CVRS success in the area of, for example, vehicle mileage or vehicle utilisation. Such external factors can be alterations in the vehicle fleet mix, the delivery volume, drivers' working conditions or the customer base. Changes in transport productivity and thus transport costs incurred by these factors must not be attributed to the use of a CVRSS, as such costs are <u>not</u> *decision relevant*. For instance:

- A change in the drivers' working hours may lead to a change in vehicle utilisation by time which may affect the size of the vehicle fleet.
- The use of larger and more cost-efficient vehicles may reduce the costs per unit delivered.
- Changes in union rules relating to the maximum utilisation of vehicle capacity by weight, which is often below the maximum legal limit, affect the number of vehicles required and the costs per unit delivered.
- Changing customers' drinking habits in terms of types of products consumed affect vehicle utilisation and thus transport costs. For instance, demand shifting from beer to wine and spirits affects the vehicle utilisation by weight and volume, as bottled goods require different loading techniques from beer stored in large containers.
- The use of new types of pallets affects the vehicle utilisation.
- Changes in the customers' order frequency and size have an impact on transport productivity in terms of vehicle mileage and utilisation.

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6 See Section 3.3.1.1, pp. 61-52.

The following results on **organisational efficiency** in operational CVRS are based on responses of up to 39 distribution sites, with the actual number of responses depending on the individual items concerned. The respondents were made aware of the above-mentioned need to identify the direct impact of CVRS on transport as well as in related areas and to consider the influence of the aforementioned external factors as appropriate. The data are analysed using descriptive statistics, such as frequency counts, medians, means and standard deviations.

3.3.2.2 Results

To take account of the situational differences among the distribution sites participating in this research, the following detailed presentation of the results is based on the use of two populations:

- The first population includes all responses to individual items. All figures or scores which are not specifically marked relate to this population.

- The second population excludes all those responses indicating that the software has failed to provide particular benefits. At the most extreme, individual sites had no or only limited benefits from using the software. The case studies, supported by findings from the survey, provide evidence that these system failures were mainly caused by inadequate implementation[7] and use of the software rather than inadequacies in the software's quality. Also, it is unreasonable to blame system failures at single depots of a brewery group on the quality of the CVRSS itself, if the same system is used successfully at the great majority of the group's other depots.

  Consequently, results obtained from a population which ignores responses based on system failures (indicating the absence of particular benefits) are more likely to give a realistic picture of the software's full benefits. The figures or scores relating to this population are marked by an asterisk ("*").

[7] The importance of adequate implementation measures to ensure CVRS success will be discussed in Section 7.2, p. 187f.

3.3.2.2.1 Tangible benefits

3.3.2.2.1.1 Reduction in daily VRS period

CVRS can usually be carried out in a substantially shorter time than required for manual VRS. By using the software, the schedulers no longer need to spend an excessive amount of time on sorting through piles of delivery notes and manually adding up delivery weights and volumes[8]. Last-minute orders can be considered and quickly assigned to new or existing routes. A decision on whether to use their own or contract vehicles can be made instantly on the basis of readily available cost parameters.

27 out of 33 (82%) responding sites indicated a reduction in the daily VRS period. Figures 3.2 and 3.3 summarise the results[9].

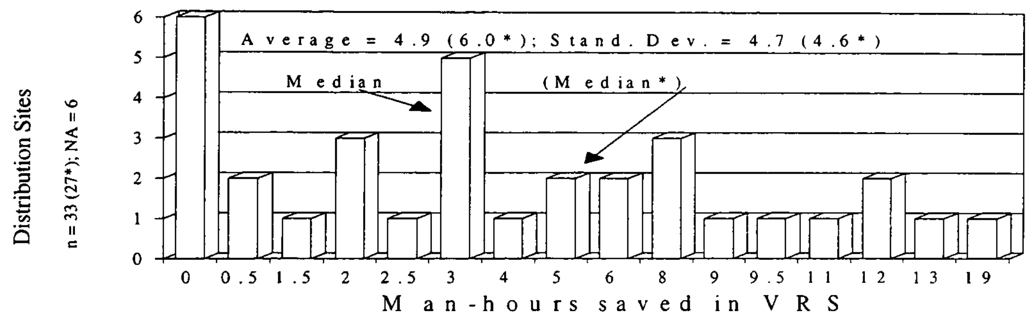

Figure 3.2: Reduction in daily VRS period

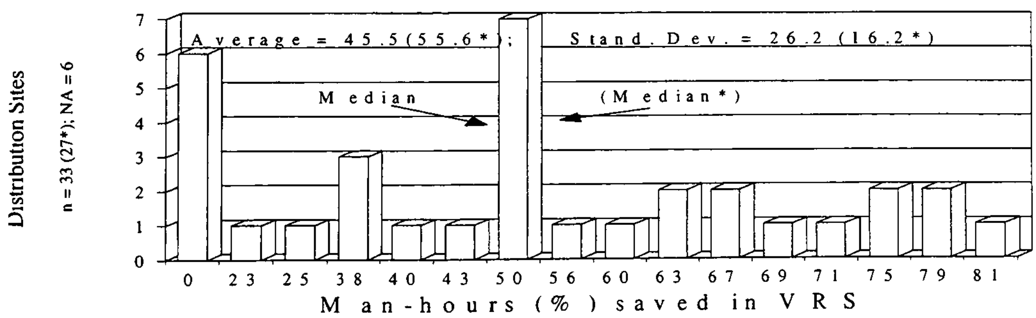

Figure 3.3: Reduction in daily VRS period as a percentage

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[8] See Section 2.4, p. 37f.

[9] Note that the figures without an asterisk ("*") relate to all distribution sites participating in the survey, irrespective of whether they had managed to reduce the VRS period or not. In contrast, the figures marked with an asterisk ("*") relate only to those distribution sites which managed to reduce the daily VRS period as a result of using CVRS.

On the basis of the schedulers' personnel costs of £5.50[10] per hour and 251[11] working days per year, the average daily saving of 6.0* hours working time equates to savings of approximately £8,300 per year. This calculation assumes that the spare working hours or redundant personnel are either re-allocated to productive work within the existing organisation or disposed of by natural wastage. A common way of reducing personnel by natural wastage is to allow for early retirement, usually with one-off redundancy payments. Also, physical distribution is notorious for operating under extreme work pressure with many important work tasks being delayed due to the hectic nature of the daily work routine. Extra working time can usually be spent on profitable activities such as the evaluation and improvement of existing procedures.

Not only has CVRS been shown to reduce the VRS period, it also increases its consistency. During the previous manual VRS, periods of peak demand often resulted in unpredictable overtime work for the schedulers. The increase in the consistency of the VRS period is of particular benefit in view of the central position of the VRS function within the organisation. Any delays occurring here affect dependent work procedures in the warehouse and associated areas.

3.3.2.2.1.2 Improved transport efficiency

The research provides strong evidence for the software's positive impact on a firm's transport efficiency in terms of vehicle mileage and vehicle utilisation.

Compared with manual VRS, which is typically based on the generation of fixed or semi-fixed routes, CVRS generally allows for a more flexible allocation of orders to trips and routes[12]. Thus CVRS aims to allocate the available vehicle resources in a cost-optimum way, with consideration of all specified delivery constraints.

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10 The figure is based on data from the annual distribution salary survey of the Reward Group [June, 1993]. The survey indicates an average basic salary of £9,549 per annum for a dispatch clerk or scheduler. Adding to this the Employer's National Insurance contribution of 10.4% at the time of writing this document, the annual personnel costs amount to approximately £11,000. Assuming a yearly work time of 2008 hours (8 hours per day and 251 days per year; see following footnote), the personnel costs for a scheduler are approximately £5.50 per hour.

11 Calendar days (365) - Saturday and Sundays (104) - UK Bank holidays excluding special holidays in Scotland and Northern Ireland (10) = 251

12 See Section 2.4, p. 37f.

Due to the software's high operating speed, the automatic generation of an initial route proposal[13] for transport problems of average size and complexity often requires less than 5 to 10 minutes. This enables the schedulers to perform various planning scenarios with differently set parameters and thus evaluate how, for instance, changes in the shift lengths, the departure times from the depot, or the fleet mix affect the quality of planning results.

In addition, the software's initial route proposal can be enhanced by the availability of comprehensive and effective interactive planning options. For instance, using the keyboard, or more conveniently, a mouse, orders can be moved efficiently between routes, and routes can be amalgamated or split up. The software immediately informs the operator about the impact which each change has made on planning parameters such as mileage, time or costs (in total and by route).

Much of the increase in transport efficiency observed in this research can undoubtedly be attributed to the software's powerful optimisation algorithms, processing speed and freedom from error. However, there is some evidence to suggest that transport productivity is also enhanced simply by the availability of the software and its incentive to raise standards as well as individuals' general cost consciousness. Ultimately, the improvements in transport productivity may result in a direct or indirect reduction in the vehicle fleet size and thus savings in capital expenditure. Direct reductions in the fleet size are achieved by either selling vehicles or no longer replacing some of the old vehicles. If the increase in transport productivity goes hand in hand with an increase in a firm's overall delivery volume, vehicles may be saved indirectly by not investing in additional vehicles. The improved transport efficiency will be discussed in further detail below:

Reduction in vehicle mileage

28 out of 37 (76%) responding sites indicated savings in vehicle mileage. Evidence from the case studies and expert interviews conducted within this research, which is supported by findings of some past studies [Holt and Watts, 1988; Fehr and Fontaine, 1987; Waters, 1986; Waters, 1984; Foulds et al, 1977], suggest that typical savings range from 5% to 15% of the vehicle mileage covered prior to using CVRS. The minimum reduction

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[13] See Section 2.6, p. 46f.

in mileage of 5% would result in savings of approximately £10,000 per annum. This calculation[14] assumes a typical vehicle fleet size composed of :

- 25 HGVs with 17 tonnes loading capacity each,
- a minimum annual mileage of 25,000 miles per vehicle,
- running costs of 31 pence per mile including costs for fuel, oil, tyres and maintenance [Motor Transport, 1992].

Improved vehicle utilisation

28 out of 37 (76%) respondents reported that the software led to an increase in vehicle utilisation by weight and/or time. By aiming to optimise the use of human and vehicle resources available, the software generally highlights the need for curbing some of the previous cost-inefficient work procedures. For instance, vehicles were frequently dispatched with only half loads and drivers tended to finish their work early. Also, having had the possibility to specify the delivery sequence to their own discretion the drivers were often pre-occupied with being able to take breaks at "convenient" times and locations rather than aiming to maximise transport efficiency.

Reduction in the vehicle fleet size

26 out of 35 (74%) sites indicated the saving of at least one 16 or 17 tonne HGV. Figures 3.4 and 3.5 summarise the vehicles saved in nominal terms and relative terms respectively.

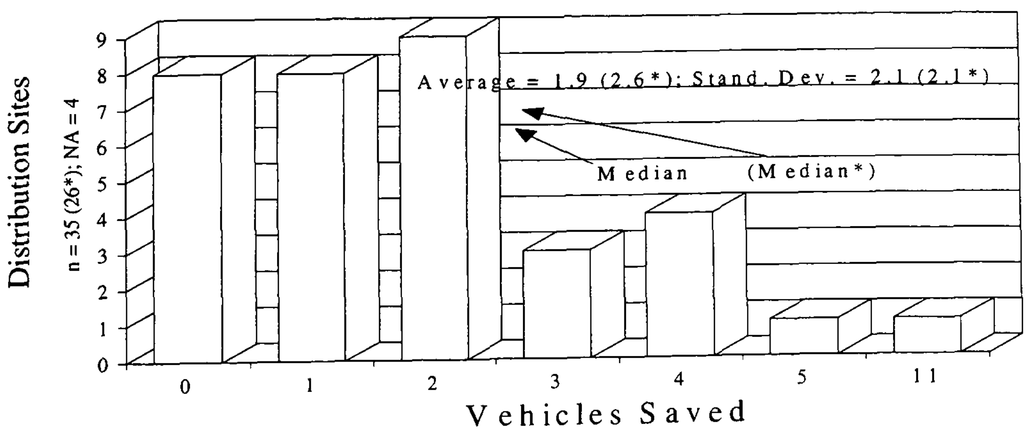

Figure 3.4: Number of vehicles saved

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[14] Calculation: 5% x 25,0000 miles x 25 HGVs x £0.31 per mile.

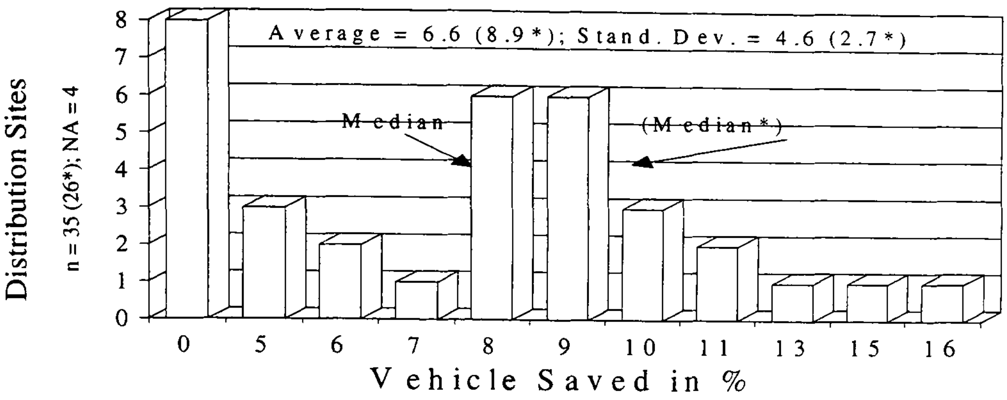

Figure 3.5: Vehicles saved as a percentage of total fleet

Reduction in vehicle crew size

As most delivery vehicles were manned by one driver and an assistant or mate, the average site was able to reduce the driving personnel by 4.0 (5.2*) drivers. The savings ranged from 0 (2*) drivers to 22 (22*) drivers. As with the savings of personnel costs for vehicle schedulers discussed earlier[15], drivers' personnel costs can only be shed if their spare working hours are either re-allocated to productive work practices within the existing organisation or the personnel are disposed of by natural wastage. Again, at most distribution sites either possibility was available.

Reduction in drivers' overtime work

At 29 out of 35 (83%) sites the software helped to reduce the drivers' overtime work. This was a result of the software's benefit of significantly reducing the daily VRS period and making it more consistent. Also, and perhaps most importantly, CVRS induced a stricter consideration of the daily order dead-line. This requirement strongly distinguishes CVRS from manual VRS. The latter may also operate on the basis of a daily order cut-off time, but, due to the considerably longer daily planning period, tends to adhere to the dead-line less strictly. The above changes enabled all daily routes and associated drivers' working time to be planned together at a given point in time as opposed to throughout the day. This generally resulted in a more effective use of the available human and vehicle resources, thus avoiding idle times or overtime work for drivers. Figure 3.6 summarises the results[16].

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[15] See Section 3.3.2.2.1.1, p. 69f.

[16] The indicators used to measure the impact of CVRS on **drivers' overtime work** are based on a *Likert type five-point ordinal scale*; see Section 3.3.2.1 ("Selection of scales"), p. 66.

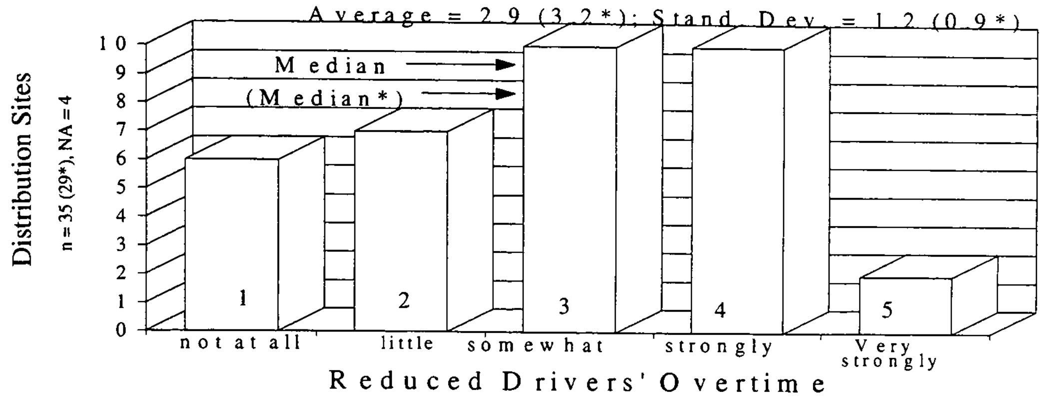

Figure 3.6: Reduction in drivers' overtime work

3.3.2.2.1.3 Reduction in warehouse staff's overtime work

17 out of 32 (53%) sites reported reductions in overtime work for warehouse staff. This was a result of the enhanced discipline in handling the daily order dead-line which made the work procedures in the warehouse more structured and time efficient. Figure 3.7 summarises the results.

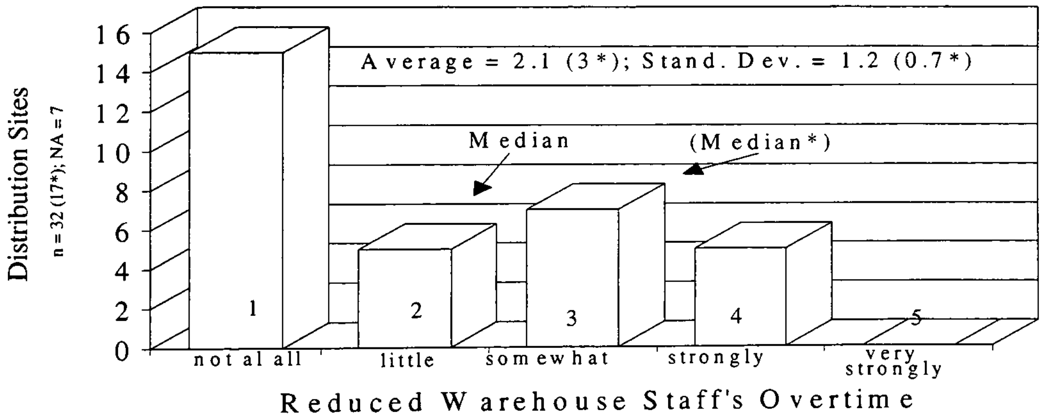

Figure 3.7: Reduction in warehouse staff's overtime work

3.3.2.2.1.4 Pay-back period

The pay-back period of CVRSSs used in an operational role can often be as short as one year or less, as demonstrated by the case of a single distribution site of Brewery-A [Eibl et al, 1994]. In 1988 the site implemented the operational CVRSS "*Visit*". It helped to reduce annual vehicle mileage by approximately 8%. Average vehicle utilisation by weight was improved by 11%. This was achieved by a more flexible allocation of orders to trips, allowed by the generation of variable routes. The increase in transport productivity allowed for direct savings of two HGVs of 17 tonnes gross vehicle weight (GVW), achieved by no longer replacing some of the written-off vehicles; these represent savings of more than 8% of the total vehicle fleet costs.

Using the software has also led to a considerable reduction in the amount of daily paperwork. The VRS period was reduced from eight man-hours to one and a half man-hours. The workforce was reduced by the loss of the previous manual route planner who took early retirement. Following a re-organisation of responsibilities, CVRS became a part-time job shared between two members of staff who conducted the work in addition to their regular tasks.

In an effort to measure the cost effectiveness of *Visit* the current research has conducted an analysis of the software's tangible costs and savings. The analysis used modern discounted cash flow (DCF) calculation techniques (Table 3.5). The strength of the DCF technique lies in its ability to take account of both the time differential of earnings on the investment and the time differential of a series of investment proposals [Wright, 1973]. It is important to realise that any such investment appraisal can only evaluate measurable financial implications which can be directly ascribed to the use of the software. Further indirect (and therefore difficult to quantify) financial implications may result from intangible benefits such as improved cost control or enhanced customer service.

Cash inflows arose from capital savings for the two vehicles including revenue savings for their annual standing and running costs. Cash inflows also occurred from revenue savings for the manual scheduler and the vehicles' drivers; that is two drivers and their two assistants who were offered vacant jobs in the warehouse or the opportunity of early retirement. The calculation assumes that no extra charges and thus cash outflows have occurred due to schedulers' early retirement. Cash outflows occurred from capital expenditure for both the computer hardware and software including costs for implementation and training as well as revenue expenditure for the software's maintenance.

The discount rate used in the calculation is 15%, representing the company's average cost of capital. All cash flows have been adjusted for inflation by an average rate of 5% per annum, which represents the approximate annual increase in the retail price index during the period of the investment appraisal [Bank of England, 1993].

The calculation also considers cash-flow implications in relation to capital allowances (capital tax) and revenue tax with the company's corporate tax being 35%; that is, cash inflows from capital allowances on capital expenditures on plant, machinery or other fixed assets, in this case the purchase of software and hardware. Similarly, cash outflows arose from the loss of capital allowances on plant, machinery or other fixed assets, in this case for the investment saved on two heavy goods vehicles which were no longer replaced at a five year interval. Cash inflows and outflows from revenue tax occurred for revenue expenditures and revenue savings respectively.

	Period	0	1 (1988)	2 (1989)	3 (1990)	4 (1991)	5 (1992)
CASH OUTFLOWS	Inflation: 5% p.a.	1.00	1.05	1.05	1.05	1.05	1.05
	Software purchase & implementation incl. of training etc.	-14,241	0	0	0	0	0
	Hardware purchase	-6,000	0	0	0	0	0
	Soft-/hardware maintenance	0	-3,300	-3,465	-3,638	-3,820	-4,011
	Capital tax* **	0	-6,048	-4,536	-3,402	-2,552	-1,914
	Revenue tax**	0	-2,383	-29,238	-30,700	-32,235	-33,846
	Cash outflow per year	-20,241	-11,731	-37,239	-37,740	-38,607	-39,772
	Discount rate 15%	1.00	0.87	0.76	0.66	0.57	0.50
	Net Present Value (NPV)	-20,241	-10,206	-28,301	-24,908	-22,006	-19,886
	NPV accumulated	-20,241	-30,447	-58,748	-83,657	-105,662	-125,548
CASH INFLOWS	Investment costs 2 vehicles	69,120	0	0	0	0	88,217
	Annual vehicle standing costs	6,808	7,148	7,506	7,881	8,275	8,689
	Annual vehicle running costs	0	10,388	10,907	11,453	12,025	12,627
	Personnel costs 4 drivers	0	56,000	58,800	61,740	64,827	68,068
	Personnel costs 1 scheduler	0	10,000	10,500	11,025	11,576	12,155
	Capital tax* **		1,771	1,328	996	747	560
	Revenue tax**			1,155	1,213	1,273	1,337
	Cash inflow per year	75,928	85,307	90,197	94,308	98,724	191,653
	Discount rate 15%	1.00	0.87	0.76	0.66	0.57	0.50
	Net Present Value (NPV)	75,929	74,218	68,549	62,243	56,273	95,827
	NPV accumulated	75,929	150,147	218,696	280,939	337,212	433,039
TOTAL	CASH INFLOW/OUTFLOW						
	NPV cash out-flow	-20,241	-10,206	-28,301	-24,908	-22,006	-19,886
	NPV cash in-flow	75,929	74,218	68,549	62,243	56,273	95,827
	Total NPV (inflow - outflow)	55,688	64,012	40,248	37,335	34,267	75,941
	Total NPV accumulated	55,688	**119,700**	159,948	197,283	231,550	**307,491**

* Capital tax is the tax saved/paid as a result of capital allowances received/lost on the written down value of 25% of plant and equipment

** The company's corporate tax is 35 %

Table 3.5: Cost savings in operational CVRS

Source: Eibl et al, 1994

As shown in Table 3.5 the *Visit* system paid for itself within the first year of its usage by generating a net present value (NPV) of more than £119,000. The accumulated NPV of the system's total life time of approximately five years amounts to more than £307,000. Similar results were revealed by the in-depth case studies of Brewery-E, Brewery-F and Brewery-G (Table 3.6).

Tangible Costs and Benefits		Depot of Brewery -A	Brewery -E	Brewery -F	Brewery -G
Sys-tem	CVRSS used	Visit	Dayload	Paragon[2]	DiPS[6]
	Data of CVRSS live usage	1988	1981	1991	1992
	CVRSS implementation period (full-time man weeks)	20	24	24	18
Costs[3]	Software purchase incl. customisation (£)	10,099	20,000	15,000	30,000
	Software implementation incl. training (£)	4,142	4,000	7,500	7,000
	Hardware purchase (£)	4,000		2,500	8,000
	Software/hardware maintenance (£ p.a.)	3,300	1,400	3,000	2,300
Bene-fits	Vehicle utilisation by weight (%)	+11	+15	+10	Increase[1]
	Vehicle utilisation by time (%)	Increase[1]	Increase[1]	Increase[1]	Increase[1]
	Vehicles (number)	-2	-3	-1	Reduction[4]
	Vehicle fleet (%)	-8	-15	-10	Reduction[4]
	Drivers (number)	-4	-6	-2	Reduction[4]
	Vehicle mileage (%)	-8	-17	-6	Reduction[4]
	VRS period (hours/CVRS session)	-6.5	-13	0[2]	Reduction[4]
	VRS period (%)	-81	-75	0[2]	Reduction[4,7]
	Pay-back period (years)	<1	<1	<2	<2[5]

[1] An increase was identified, but it was not quantifiable.
[2] The use of CVRS had no impact on the VRS period, as the company previously used computerised order allocation software.
[3] Costs are shown in historical prices.
[4] A reduction was identified, but it was not quantifiable.
[5] Estimate.
[6] The company had started using the software 'live' during the time of data collection of this research. Therefore, it was not possible to quantify the system's full impact.
[7] With the implementation of the *DiPS* system the company replaced the CVRSS *Dayload* which it implemented in 1986. Consequently, as in the case of Brewery-F, the CVRS had only a small impact on the VRS period. A reduction in the VRS period was evident, but at the time of data collection not quantifiable.

Table 3.6: Tangible costs and benefits of operational CVRS in examined breweries

3.3.2.2.2 Intangible benefits

Evidence from this research suggests that many organisations do not sufficiently appreciate the intangible or qualitative benefits which CVRS can provide. This attitude may be caused by insufficient cost consciousness, inadequate management skills or perhaps by lack of awareness of the software's full benefits. Many organisations, or their personnel who decide on the purchase of IT, tend to evaluate CVRS technology predominantly on the basis of tangible cost savings achieved by a reduction in vehicle mileage or the vehicle fleet size. Evidence from this research highlights the importance of the software's intangible or qualitative benefits. These occur not only in physical distribution, but also in related areas such as finance and marketing. As many intangible benefits increase the quality of work procedures and their productivity or provide for a competitive edge in the market, they ultimately result in substantial cost savings.

Table 3.7 summarises the survey's responses to the variables relating to the intangible benefits from CVRS used in an operational role[17].

The variables are measured on a *Likert type five-point scale*[18]. Again, the results are drawn from two populations[19]. Indicators from the first population which on average score 2.5 and higher are presented in italic print. Indicators which on average score 3.0 and higher are presented in bold print.

Sub-dimension	Intangible Benefits in Physical Distribution (Indicators)	Indica-tor (label)	Mean	
+ Efficiency of VRS A	**More effective coping with delivery constraints**	A-188i	3.4	3.8*
+ Efficiency of VRS B	**More comprehensive planning options**	A-188b	3.1	3.3*
+ Efficiency of VRS C	**Increased consistency of planning results**	A-188c	3.1	3.3*
+ Efficiency of VRS D	Reduced occurrence of human errors	A-188g	2.6	3.1*
Efficiency of VRS E	*Significant reduction in paper work/sales order notes*	A-188d	2.5	3.0*
+ Efficiency of VRS F	*Improved compliance with legal regulations*	A-188o	2.8	3.1*
+ Efficiency of VRS G	Increased time to carry out work effectively	A-188h	2.3	3.0*
+ Transport control A	*Improved control over the transport operation*	A-188r	2.9	3.2*
+ Transport control B	*Improved comparison of planned data and actual data*	A-189d	2.8	3.1*
+ Transport control C	**Improved statistical analysis of distribution data**	A-188u	3.0	3.5*
+ Transport control D	*Improved transparency /awareness of transport costs*	A-188v	2.6	3.4*
Monitoring work A	*Improved monitoring of scheduler's work performance*	A-188s	2.9	3.3*
+ Monitoring work B	Improved monitoring of drivers' working hours	A-188t	2.3	2.9*
+ Dependence	**Decreased dependence on the scheduler**	A-188p	3.0	3.4*
+ Learning VRS	*Reduced time period required for learning VRS*	A-188q	2.6	2.9*
Drivers' work load	*More equal spread of delivery work over drivers*	A-189g	2.5	3.0*
Warehousing	*Smoother work procedures in the warehouse*	A-188m	2.6	3.0*
+ Software integration	*Reduced duplication of data entry and thus of errors*	A-188l	2.8	3.3*
+ Sales & Marketing A	*Improved customer service*	A-189a	2.7	3.1*
+ Sales & Marketing B	*Increased potential for acquisition of future customers*	A-189b	2.7	3.2*
Sales & Marketing C	Extended period of order acceptance	A-188j	2.2	3.0*
Sales & Marketing D	Improved coping with emergency orders/late orders	A-188k	2.4	3.0*
Sales & Marketing E	Improved negotiation of customer service level	A-189c	2.4	3.1*
Sales & Marketing F	Improved assessment of customers with cost information	A-189e	2.0	2.8*
+ Finance	Improved transport information for drivers' pay.	A-189h	1.8	2.9*

Table 3.7: Summary statistic of intangible benefits in operational CVRS

[17] For further detail see Table A2-1 (Appendix 2), p. A-28.

[18] See Section 3.3.2.1 ("Selection of scales"), p. 66f.

[19] See Section 3.3.2.2, p. 68.

The following sections amplify the above findings in further detail. The figures indicated for each variable or benefit refer to Table 3.7.

3.3.2.2.2.1 Efficiency of VRS procedure

At 32 out of 37 (86%) sites CVRS enabled delivery constraints to be coped with more effectively (A-188i: mean 3.4 (3.8*)). This particular benefit was rated highest of all items in this category. The case studies reveal that more effective coping with delivery constraints has increased customer satisfaction. Moreover, the number of unsuccessful deliveries due to missed delivery times or waiting at customer sites due to early arrival declined significantly.

33 out of 37 (90%) sites reported that the software increased the consistency of the planning results (A-188c: mean 3.1 (3.3*)). This applies in particular to the vehicle utilisation by weight and time. Many manual schedulers tend to generate single-trip routes or allow for a maximum of, for example, two trips per route, irrespective of the actual delivery volume. Also, manual VRS tends to spread the delivery work evenly over the drivers or vehicles available. Each driver is given a similar number of orders, delivery volume and vehicle mileage. There is a tendency to provide the drivers with an equal pay and thus keep them happy, rather than to maximise the transport efficiency of the vehicle fleet. As a result, vehicle utilisation and mileage can vary substantially.

In contrast, CVRS aims to maximise vehicle utilisation by both weight and time. In addition, the software minimises delivery time or vehicle mileage. Usually, both delivery time and vehicle mileage are reduced, since the fastest roads are frequently also the shortest ones. The software also typically generates more trips per route. Eventually, the software reduces the number of vehicles used. While CVRS maximises the overall transport efficiency of the vehicle fleet and keeps its level relatively constant, individual routes can vary enormously in terms of mileage and the number of orders delivered. To allow for an equal remuneration of the driving personnel, some distribution sites rotate the routes among the drivers.

31 out of 36 (86%) sites reported that the software removed the drudgery of manual VRS thus freeing the schedulers to use their expertise for carrying out their job more effectively (A-188o: mean 2.8 (3.1*)).

28 out of 36 (88%) sites indicated that the software helped to curb the occurrence of errors caused by, for example, wrong arithmetical calculations and omitted or poorly hand-written sales order notes (A-188g: mean 2.6 (3.1*)).

25 out of 34 (73%) sites reported that CVRS helped to reduce the amount of daily paperwork involved in the previous manual or computer-supported VRS procedure (A-188d: mean 2.5 (3.0*)).

Finally, 22 out of 34 (65%) sites reported that CVRS allowed for an improved compliance with legal regulations, such as drivers' working and resting times as well as the maximum loading capacity of vehicles (A-188o: mean 2.8 (3.1*)).

3.3.2.2.2.2 Transport control

The great majority of 30 out of 35 (86%) sites benefited from improved control over their transport operations through the software's provision of accurate and reliable reports on vehicle mileage, vehicle utilisation and time schedules in relation to, for example, driving times and working time spent at customers' premises (A-188r: mean 2.9 (3.2*)). The availability of such reports continuously informs management about current and past levels of performance. Any deviations from average performance levels can be identified instantly and analysed to discover their causes. Some breweries such as Brewery-C and Brewery-B use some of the transport information provided by the CVRSS for further processing in special management information systems.

Also with the aim of improving cost control, 29 out of 33 (78%) respondents used the software's output information for routine comparison with actual transport data captured by the tachograph or vehicle on-board computer (A-189d: mean 2.8 (3.1*)). This enables any deviation between the proposed and actual transport data to be identified and investigated. Corrective actions can be taken as appropriate.

29 out of 36 (81%) sites stated the software allowed for an improved statistical analysis of distribution data thus providing useful management information. The benefit was rated highest of all variables in this class (A-188u: mean 3.0 (3.5*)). The software typically provides daily and weekly route statistics including information on the number of orders, mileage covered, average utilisation of vehicles, average speeds, average delivery per customer, order frequency per customer and transport volume per mile. Thus, CVRS

increases the transparency of the distribution environment. Every element within the distribution chain and environment is recorded with great accuracy and, where appropriate, quantified in terms of time and/or costs. This highlights any existing "slack" caused by unfavourable customer order patterns and ineffective staff work practices.

For instance, the analysis of past distribution data may reveal that two customers, who are located in the same street receive regular deliveries on different days of the week. This situation would suggest the need to harmonise delivery days and times, thus increasing transport efficiency. Similarly, the analysis may reveal excessively high order frequencies and small order quantities of certain customers for which the delivery conditions may need to be re-negotiated

Finally, 25 out of 36 (69%) sites felt that the software improved the transparency of costs involved in transport operations and subsequently increased the general awareness of physical distribution costs (A-188v: mean 2.6 (3.4^*)).

3.3.2.2.2.3 Monitoring work performance

At 25 out of 36 or at 69% of the sites the software helped management to more effectively monitor the vehicle schedulers' work performance (A-188s: mean 2.9 (3.3^*)). The documentation of distribution data and the availability of transport statistics made the VRS routine more transparent. Management has been enabled to identify and question negative deviations of the schedulers' performance from the average performance standards of past periods. At the same time, management has been given an effective means of measuring an increase in the schedulers' performance and thus can give them credit or reward them as appropriate. Also, management has acquired the ability to set performance targets, for example, in terms of average tonnes delivered per route or trip.

Brewery-C has introduced a procedure where the operational transport managers at the distribution sites are given printouts of the initial route proposals automatically generated by the CVRSS. These printouts are compared with the final routes which have been interactively modified by the schedulers. This procedure allows management to evaluate the schedulers' performance and question whether the changes made were justified. Consequently, the vehicle schedulers are forced to consider the cost implications of their decisions made in CVRS. This is believed to have sharpened the schedulers' cost consciousness and substantially curbed the habit of some schedulers to plan "easy" and cost inefficient routes for the sake of minimising the level of conflict between themselves and the drivers.

Similarly, 25 out of 35 (69%) sites used the software for monitoring the drivers' work performance (A-188t: mean 2.3 (2.9*)). With the availability of CVRS, management no longer needs to rely on drivers' judgements of the feasibility of routes and associated travel distances and times. Instead, the software provides detailed and accurate transport statistics against which the drivers need to defend their position. This information enables management to curb the drivers' habit of finishing early, thus making full use of the vehicles and human resources available. Also, it has become possible to measure increases in the drivers' work performance and reward or remunerate the personnel accordingly.

3.3.2.2.2.4 Other benefits in transportation

Learning VRS: At 31 out of 36 (86%) sites the use of CVRS substantially reduced the overall time required to learn the job of VRS (A-188q: mean 2.6 (2.9*)). This is primarily due to the fact that CVRS is based on the documentation or storage of distribution data in the software's database rather than in the memories of the load planners.

Dependence: 31 out of 36 (86%) sites reported that the software decreased the sites' dependence on the schedulers (A-188p: mean 3.0 (3.4*)). This is because CVRS can be learned substantially more quickly than manual VRS, resulting in easier replacement of personnel in case of illness, absence during holidays or leaving the company.

Drivers' remuneration: Finally, at 25 out of 33 (76%) sites the software's provision of daily, weekly or monthly transport statistics helped in spreading the delivery work over the available drivers on a more equal basis, usually by rotating routes (A-189g: mean: 2.5 (3.0*)). This has led to a fairer remuneration of the workforce, which in turn improved labour relations, work motivation and work performance.

3.3.2.2.2.5 Benefits in inventory and warehousing

At 28 out of 36 (78%) sites the software enabled the warehouse departments to smooth out the work procedures (A-188m: mean 2.5 (3.0*)). Since the daily work load is planned in a substantially shorter time there is more time available in the warehouse for order picking, load assembling and vehicle loading.

3.3.2.2.2.6 Software integration

At 25 out 36 (77%) sites the software helped to reduce the duplication of data entry and the associated occurrence of errors (A-188l: mean 2.8 (3.3*)). During manual route planning, the data describing the planned routes needed to be inserted manually into other software systems, such as the software for generating picking and loading lists. Using CVRS has enabled this to be done automatically, ultimately improving the efficiency and effectiveness of the existing software systems. Repeated data entry is avoided, with the order data usually being recorded and entered into a computerised sales order processing system also known as 'telesales' (telephone sales). From this point until the delivery of the goods to and the subsequent invoicing of the customers the data are stored in central databases. These can be accessed by various software systems. All Breweries have integrated their CVRSSs with their sales order processing software and warehouse software which generates picking and vehicle loading lists.

3.3.2.2.2.7 Benefits in sectors other than physical distribution

Sales and marketing

Over the past 10 years customer service demands in the British brewing industry have risen sharply. Customers have demanded higher order frequencies with the aim of reducing stock and thus minimising the amount of wastage as well as the capital tied up. In addition, they have increasingly tightened their delivery time windows which in the late seventies were practically non-existent for many breweries. Customers used to be happy to receive their goods on a given day, largely ignoring the actual time of delivery.

The general rise in customer service requirements has led to an increasingly restricted environment in which breweries have to operate. The trend has been reinforced by the regulations laid down by the Department of Trade and Industry in November 1989, following the Monopolies and Mergers Commission's investigation of the industry [Jordans & Son Ltd., 1989]. As a result, many breweries have had to release a substantial proportion of their tied houses; these have been turned into free trade houses. Subsequently, the breweries were forced to compete against other breweries in regaining their former tied houses. This has ultimately led to a significant rise in the overall service level.

As a result of the sharp increase in customer service demands, breweries increasingly consider CVRS technology to be a significant means not only of reducing costs, but also of effectively coping with customer service demands. In fact, at 28 out of 35 (80%) sites the marketing and sales function benefited from improved customer service in terms of fewer omitted orders, shorter lead times and more precise time schedules (A-189a: 2.7 (3.1*)). Enhanced customer service is particularly important in typical buyer markets like the food and drinks industry, which is ruled by the consumer demand and where large quantities of goods need to be actively "sold against" competing organisations [Weidner, 1980].

Some of the large companies (Brewery-A, Brewery-B, Brewery-C) participating in this research reported the intention to reduce their order lead time[20] from currently 48 hours to 24 hours in the near future. This significant enhancement of the customer service may become possible, because of the software's ability to significantly reduce the daily VRS period[21].

At 25 out of 36 (69%) sites the increase in customer service gained was valued as a competitive advantage, which significantly increases the potential for the acquisition of future customers (A-189b: mean 2.7 (3.2*)).

At 21 out of 32 (66%) sites the software was used to conduct simulations of transport operations indicating the impact of customer-related delivery constraints or service expectations on the "quality" of routes or transport costs (A-189c: mean 2.4 (3.1*)). This assists the sales marketing function to determine the general customer service level or negotiate certain service levels with individual customers.

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[20] *Order lead time* is the period between order placement by the customer and the delivery of goods.

[21] See Section 3.3.2.2.1.1, p. 69f.

The flexibility provided by the software makes coping with "emergency" or late orders more effective, as these can be quickly added to existing routes, provided that the order assembling and loading of the vehicles have not commenced. The software immediately informs the scheduler about the impact of the changes made (A-188k: 2.4 (3.0*)).

Because the software facilitates a significant reduction in the VRS period, 21 out of 35 (60%) sites managed to extend the daily period of order acceptance (A-188j: mean 2.2 (3.0*)).

Finally, the improved availability of cost information provided by the software has helped operators in assessing the profitability of their customers in terms of transport costs per delivered unit, order etc. The software was used for this purpose at 16 out of 29 (55%) sites (A-189e: mean 2.0 (2.8*)).

Finance

In the brewing industry the drivers' payroll commonly consists of both a fixed salary and a bonus scheme based on delivered units and covered mileage. The bonus usually accounts for a substantial part of the pay scheme. At 25 out of 33 (76%) sites the payroll section benefited from the software's provision of readily available and documented transport information (A-189h: mean 1.9 (2.9*)).

3.3.3 User satisfaction in CVRS

3.3.3.1 Measurement of variables

Operationalisation of concepts

For convenience, the operationalisation of the **CVRS user satisfaction** concept is presented in the subsequent Table 3.8[22] together with a summary of the responses from the survey.

As with the operationalisation of **organisational efficiency**, certain dimensions and sub-dimensions are expected to be particularly important in relation to the overall **CVRS**

[22] See Table 3.8, p. 88.

user satisfaction concept measured. The *important* dimensions and sub-dimensions are labelled with a plus ("+").

Selection of scales

All items were measured by indicators based on a *semantic differential seven-point scale* which was developed by Charles Osgood, George Suci and Percy Tannenbaum [Osgood, 1962]. The "semantic differential has been shown to be sufficiently reliable and valid for decision making and prediction in marketing and the behavioural sciences" [MacDaniel and Gates, 1991, p. 363]. The scale is based on a dichotomous (opposite) or bi-polar pair of adjectives or adverbs that are used to describe the characteristics of concepts and objects. The respondents are asked to rate the concepts on a scale of 1 to 7.

Following the empirical study of Bailey and Pearson [1983] the *semantic differential (ordinal) scale* used in the current research has been slightly extended in such a way that the response categories have been denoted by the adverbial qualifiers *very*, *quite*, *slightly*, *neither/equally*. In addition, a further category was added to allow for the response "don't know" or (item) "does not apply". An example of the scale and its associated indicator is shown in Figure 3.8.

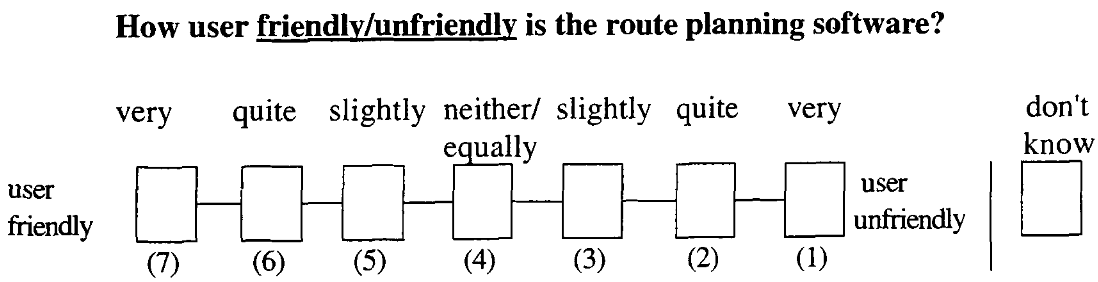

Figure 3.8: Example of an indicator based on a *semantic differential seven-point scale*

A respondent's most "positive" or "good" rating (in this case, the first category to the left) accounts for a score of 7 and the most "negative" or "bad" rating for a score of 1 (in this case, the first category to the right).

McDaniel and Gates [1991, p. 363] suggest that to "partially avoid the 'halo effect', the scale adjectives should be randomly reversed so all of the 'good' phrases are not placed on one side of the scale and the 'bad' on the other". This suggestion was generally not followed in the current research. The decision not to do so was motivated by the concern that, given the extreme length of the questionnaires, the random reversal would probably have confused the respondents. This concern was traded off against the possible occurrence of the "halo effect". The latter is said to mean that "the rating of specific image components may be dominated by the interviewee's overall impression of the concept being rated. This may be a significant bias if the image is hazy in the respondent's mind" [McDaniel and Gates, 1991, p. 363].

Data analysis

CVRS success in terms of **CVRS user satisfaction** is measured on the basis of responses given by up to 96 managers and schedulers. The actual number of responses to individual indicators varies, as some respondents were unable or unwilling to answer certain indicators. Some indicators were addressed to both managers and schedulers, others were addressed to each group individually. Since the two groups gave similar responses, the groups were pooled as appropriate. As mentioned earlier, indicators concerning the drivers were answered by the managers and schedulers. The responses with respect to the drivers are averaged for each indicator[23].

The data are analysed using descriptive statistics, such as frequency counts, medians, means and standard deviations. Indicators which score 5.0 or higher on average are presented in italic print. Indicators which score 5.5 or higher on average are presented in bold print.

3.3.3.2 Results

The results of the data analysis are presented together with the operationalisation of the **CVRS user satisfaction** concept in the following Table 3.8 which shows the mean responses[24].

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[23] See Section 1.4.1.2 ("Survey of current, potential and past users of CVRS in the brewing industry"), p. 17f.

[24] For further detail see Table A2-2 (Appendix 2), p. A-29.

Concept	Dimension	Sub-dimension	Indicator (contents)	Indicator	Mean
CVRS user satisfaction	+ General CVRS user satisfaction	(not applicable)	M/S: *Overall satisfaction with CVRS*	H-149	5.3
			D: Overall satisfaction with CVRS	H-151d	3.8
			M/S: **General happiness about company's use of CVRS**	H-157	5.9
			D: General happiness about company's use of CVRS	H-158d	3.8
			M/S: **General usefulness of CVRS for company's requirements**	H-159	5.8
			D: General usefulness of CVRS for company's requirements	H-161d	3.7
			M/S: **Retrospective support of CVRS implementation**	H-166	5.9
			D: Retrospective support of CVRS implementation	H-167d	3.4
			M/S: *Overall superiority of CVRS compared to manual VRS*	H-168	5.6
			M/S: *Ability of CVRS to meet overall requirements in distribution*	H-169	5.2
			M/S: Ability of CVRS to meet daily transport requirement	H-170	5.0
	User's satisfaction with technical features of CVRS	+ Use	M/S: **Level of user friendliness**	H-88	5.5
		+ Interactivity	M/S: *Quality of interactive features*	H-89	5.0
		+ Control	M/S: *Level of control over program operations*	H-90	5.1
		+ Command intelligibility	M/S: *Intelligibility of command structure/language*	H-91	5.3
		+ Command efficiency	M/S: **Efficiency of command structure/language**	H-92	5.5
		+ Command flexibility	M/S: *Level of flexibility to adjust to new conditions, demand etc.*	H-93	5.0
		Error recovery	M/S: Quality of error recovery facilities	H-94	4.6
		Response time	M/S: *Time elapsed between service request and software's reply*	H-95	5.0
		Data security	M/S: *Quality of facilities for protection against data loss*	H-96	5.3
		Access security	M/S: *Quality of facilities for protection against unauthorised access*	H-97	5.0
		+ Consistency	M/S: Consistency of planning results	H-98	4.8
		+ Reliability	M/S: Reliability of planning results	H-99	4.9
		Report information	M/S: *Comprehensiveness of reports' output information*	H-100	5.4
		Report layout	M/S: **Clarity of layout and display of reports' output content**	H-101	5.8
		Report control	M/S: Effectiveness of facilities to control display of report format	H-102	4.0
		Graphs	M/S: Benefits of arrays of graph formats (bar, histogram etc.)	H-103	3.3
		Analysis	M/S: Benefits of data analysis features using statistical methods	H-104	4.2
		Documentation	M/S: Quality of documentation	H-105	4.9

"M" = Indicators addressed to distribution/transport managers; "S" = Indicators addressed to schedulers (CVRS operators);
"D" = Indicators addressed to managers and schedulers on behalf of drivers (responses were averaged)

Table 3.8: Operationalisation of the *CVRS user satisfaction* concept and mean scores of responses

Concept	Dimension	Sub-dimension	Indicator (contents)	Indicator	Mean
CVRS user satisfaction	Satisfaction with ability of CVRS to meet a company's specific require-ments in physical distribution	+ Transport A	M/S: *Capability of CVRS to deal with general delivery constraints*	H-106	5.2
		+ Transport B	M/S: *Capability of CVRS to deal with customer time windows*	H-107	5.2
		+ Transport C	M/S: *Capability of CVRS to deal with vehicle access restrictions*	H-108	5.1
		+ Transport D	M/S: *Quality of "CVRS routes" compared to "manual routes"*	H-109	5.4
		Order processing A	M/S: Technical convenience of interfacing CVRSS with other software	H-110	4.7
		Order processing B	M/S: *Technical convenience of transfer of daily orders to CVRS*	H-111	5.3
		Order processing C	M/S: *Speed of daily data transfer from order processing to CVRSS*	H-112	5.1
		Warehouse	M/S: Capability of achieving cost savings in customer allocations	H-113	4.5
		+ Customer base	M/S: Average time required for processing daily orders at depot	H-114	4.7
		+ Delivery area A	M/S: *Accuracy of "CVRS routes" compared to "manual routes"*	H-115	5.4
		+ Delivery area B	M/S: **Accuracy of road database reflecting road infrastructure**	H-116	5.6
		+ Delivery area C	M/S: **Flexibility of road database's adaptation to road infrastructure**	H-117	5.6
		Compatibility	M/S: *Adaptability of CVRS with hardware and peripheral machines*	H-118	5.4
	Users' CVRS work satisfaction	+ Work routine A	S: *Impact of CVRS on schedulers' work routine*	H-134	5.0
		Work routine B	D: Impact of CVRS on drivers' work routine	H-154d	3.1
		Work environment	S: *Impact of CVRS on schedulers' work environment*	H-135	5.1
		Responsibilities	S: *Change in level of schedulers' responsibilities*	H-127	5.1
		Work contents	S: Impact of CVRS on schedulers' number of work areas and issues	H-136	4.4
		+ Performance A	S: **Usefulness of CVRS for performing schedulers' job**	H-145	5.6
		Performance B	D: Usefulness of CVRS for performing drivers' job	H-163d	3.4
		Work atmosphere	M: Change in work atmosphere between managers and schedulers	H-155	4.2
		Work atmosphere B	M: Change in work atmosphere between managers and drivers	H-156	3.9
		Work atmosphere C	S: Change in work atmosphere between schedulers and managers	H-128	4.3
		Work atmosphere	S: Change in work atmosphere between schedulers and drivers	H-129	3.9
		Work difficulty A	S: Impact of CVRS on schedulers' level of work difficulty	H-130	4.4
		Work difficulty B	D: Impact of CVRS on drivers' level of work difficulty	H-152d	3.4
	CVRS personal satisfaction	Self-esteem A	S: *Impact of CVRS on schedulers' self-esteem*	H-125	5.0
		Self-esteem B	D: Impact of CVRS on drivers' self-esteem	H-153d	4.0
		+ Work interest	S: **Level of interest in CVRS**	H-137	5.9
			S: **Level of challenge provided by new demands of CVRS**	H-138	5.9

"M" = Indicators addressed to distribution/transport managers and scheduler respectively; "S" = Indicators addressed to schedulers (CVRS operators);
"D" = Indicators addressed to managers and schedulers in behalf of drivers (responses were averaged)

Table 3.8 (continued): Operationalisation of the *CVRS user satisfaction* concept and mean scores of responses

The following paragraphs outline the above findings of Table 3.8 in further detail.

General CVRS satisfaction

On average the managers and schedulers indicated a rather high level of **general CVRS satisfaction** (means: 4.9 to 5.9 on a *semantic differential seven-point scale*)

In contrast, the drivers appear to take a rather neutral or slightly negative view on the use of CVRS (means: 3.7 and 3.9). Hence, drivers seem to be seeing no direct benefits arising from CVRS.

The drivers' ratings of **general CVRS satisfaction** are considerably lower than the ratings of the managers and schedulers. These findings were anticipated and confirm the results of Bargl's [1994] recent study on the use of CVRS in the German road transport industry.

Overall, the findings suggest that the users of CVRS are generally satisfied with CVRS. There is good reason for weighting schedulers' and managers' satisfaction higher than that of the drivers. This is because managers are responsible for the effective use of the software and the schedulers are most affected by it.

Technical features of CVRS

Overall, the managers and schedulers are moderately satisfied with the technical features of their CVRSS.

The lowest average level of satisfaction was indicated with respect to the sub-dimension **graphs** (mean: 3.3). This suggests that CVRS users either have no need of graph facilities such as histograms, line and bar diagrams, or that the facilities tend to be ineffective. Comparatively low average scores were also indicated regarding the sub-dimension **analysis** (mean: 4.2) which refers to the perceived benefits of data analysis features using statistical methods. Again, CVRS users either do not need such features or the features are lacking in effectiveness.

The highest average satisfaction was indicated with respect to sub-dimensions concerning the *use* or *handling* of CVRS technology as follows:

- **report layout** (mean: 5.8);
- **command efficiency** (mean: 5.5);
- **user friendliness** (mean: 5.5);
- **command intelligibility** (mean: 5.3);
- **command flexibility** (mean: 5.0);
- **control** (mean: 5.1);
- **interactivity** (mean: 5.0); and
- **response time** (mean: 5.0).

High mean scores of satisfaction were also indicated regarding the sub-dimensions relating to *security*, these being **data security** (mean: 5.3) and **access security** (mean: 5.0).

Ability to meet specific distribution requirements

Overall the managers and schedulers are well satisfied with the ability of the software to meet their organisations' or distribution sites' specific requirements in physical distribution.

Ten out of 13 sub-dimensions tested were rated with average scores of 5.0 and higher. Nearly all of these sub-dimensions were marked or *weighted* with a "+" which indicates their estimated disproportionally high importance in relation to the overall **CVRS user satisfaction** concept. The highest average ratings were indicated with respect to the users' satisfaction with the quality of the software's road database (**Delivery area A** - mean: 5.4; **Delivery area B** - mean: 5.6; **Delivery area C** - mean: 5.6). These findings suggest that the road databases of CVRS technology overall live up to the users' expectations.

CVRS work satisfaction

Overall, the schedulers expressed a good level of satisfaction with the software's impact on their work routine, environment and responsibilities. The corresponding sub-dimensions (**work routine A**, **work environment**, **responsibilities**) scored on average 5.0 and higher. The highest rating was indicated regarding the schedulers' feeling that CVRS is a useful means of performing their job (**Performance A** - mean: 5.6).

Significantly lower scores of work satisfaction were testified by the drivers. They indicated a slight dissatisfaction with the software's impact on their work routine (**Work routine B** - mean: 3.2). Similarly, the drivers were slightly dissatisfied or, at best, indifferent, about the software's usefulness for performing their job (**Performance B** - mean: 3.6).

Overall "neutral" views were indicated regarding the software's impact on the work atmosphere between managers, schedulers and drivers (**work atmosphere A to D** - means: 3.9 to 4.3). This suggests that the CVRS users generally managed to cope effectively with the friction between individuals which the implementation of CVRS tends to cause.

The schedulers indicated a rather neutral to slightly satisfied view towards the software's impact on the level of their work difficulty (**work difficulty A** - mean: 4.4). With respect to the software's impact on the work difficulty of the drivers, the latter reported a slight dissatisfaction or, at best, a neutral view (**work difficulty B** - mean: 3.5).

Personal CVRS satisfaction

Overall, the use of CVRS positively affects the schedulers' personal satisfaction. This is reflected by the software's positive impact on their self-esteem (**self esteem A** - mean: 5.0). Also, schedulers find the use of CVRS interesting and challenging (**work interest** - means: 5.9; 5.9).

Not surprisingly, the software failed to have a significant positive impact on the drivers' self-esteem (**Self esteem B** - mean: 4.0).

3.4 Summary

The above evidence clearly supports *hypothesis 1* suggesting that CVRS used in a strategic-tactical and operational role is a successful technology in that it increases organisational efficiency in the brewing industry. Moreover, the software leads to satisfaction on the part of the managers responsible for its effective use and also on the part of the schedulers most affected by it.

Most of the commercial CVRSSs available at the time of the current research cost between £20,000 and £50,000[1]. Add to this £8,000 for training and the software's implementation, £3,000 for computer hardware and £3,000 annual software maintenance, the software's total investment amounts to between approximately £46,000 and £76,000 for the first five years of usage. In nominal terms, this appears to be a rather expensive technology. However, when compared with the software's impact on organisational efficiency in both physical distribution and related business sectors, as well as positive impacts on individuals' satisfaction, the technology is clearly good value for money.

Organisational efficiency

In both strategic-tactical and operational CVRS the pay-back period can often be as short as one year, with the actual period depending on the size of the individual users' operations.

The users of strategic-tactical CVRS manage to reduce distribution costs by 4% to 10% per annum including costs for vehicles, drivers and inventory/warehousing

The users of operational CVRS achieve transport cost savings of 5% to 16% and nearly 9%[*2] on average. The VRS period has been reduced by an average of 6 hours or 56%[*3]. These results generally confirm the savings proposed by the CVRS suppliers.

Moreover, there are intangible or "soft" benefits such as improved control of transport operations or enhanced customer service. These can be significant and ultimately also result in substantial costs savings.

The full comparison of the tangible benefits of the current research with the findings of past empirical studies is limited due to differences in use of nomenclature and methodology. Nevertheless, the current findings confirm the results of some past studies.

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1 An overview of CVRSSs available on the British market in 1994 is shown in Table A6-1 (Appendix 6), p. A-38.

2 This figure is based on sites from the "second population", these being sites which managed to reduce the vehicle fleet. See Section 3.3.2.2, p. 68.

3 This figure is based on sites from the "second population", these being sites which managed to reduce the VRS period. See Section 3.3.2.2, p. 68.

Other studies, in contrast, indicate significantly higher savings[4]. This situation may be an indication of the rather conservative approach to measurement adopted by the current research suggesting that the savings identified are minimum estimates. An alternative explanation may be the predominantly large size of the organisations investigated in past research on CVRS. With larger organisations tending to have more "slack" in their transport operations, the use of CVRS may allow for higher savings in terms of mileage and vehicles. Also, CVRS requires only fractionally more time to generate route proposals for large VRS problems than compared with small ones. Therefore, large fleets usually achieve disproportionally high relative savings in the VRS period.

It is interesting to point out that the findings of the current research are in particular supported by evidence supplied by Bargl's [1994] recent study on the use of CVRS in the German road transport industry. Using a complex cost calculation technique comparing transport costs and associated transport quantities before with those after the implementation of CVRS, Bargl reveals average cost savings of 9.8%. He also shows that the organisations investigated managed to reduce their VRS period by 35% on average.

User satisfaction

The users of CVRS are generally satisfied with both the software's technical features and its ability to effectively deal with specific operating constraints. A rather neutral effect of CVRS was observed in the area of the work atmosphere between managers, schedulers and drivers. In contrast, CVRS significantly enhances the schedulers' personal satisfaction. It removes the drudgery of manual VRS and thus makes VRS a more interesting and challenging task.

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[4] See Table 3.1, p. 52.

Chapter 4: Adoption of CVRS

4.1 Introduction

Chapter 3 has provided overwhelming evidence that the use of CVRS technology is successful in providing substantial tangible and intangible benefits. Moreover, the software has a positive effect on work satisfaction and personal satisfaction. It would be reasonable to suggest, therefore, that the use of CVRS has become common among fleet operators. Nevertheless, existing studies as well as the preliminary research of the current study indicate that the brewing industry and the road transport industry as a whole are reluctant to adopt such software. This leads the author to suggest the following hypotheses:

Hypothesis 2a: The availability of CVRS technology has not led to the degree of usage in the road transport industry in 1993 that its success would seem to justify.

Hypothesis 2b: The availability of CVRS technology has not led to the degree of usage in the brewing industry in 1992 that its success would seem to justify.

Evidence

The findings of the research give strong support to hypotheses 2a and 2b. The evidence is based on a comparison between the market potential of CVRS technology and the current use of the technology. This comparison was carried out for both Britain's brewing industry in 1992 and the road freight industry as a whole in 1993.

4.2 Market potential of CVRS technology

4.2.1 Evaluation criteria

Strategic and tactical CVRS

Strategic-tactical[1] CVRS comprises medium-term to long-term planning tasks. Typical tasks are specifying the vehicle fleet mix, fixing delivery days and times, identifying cost-optimum depot locations and allocating customers to depots. Strategic-tactical CVRS is usually operated by medium-sized to large organisations with large fleets and/or several depots. The software tends to be used by operating centres other than distribution depots, for example logistics departments or similar service departments.

Therefore, the potential market of strategic-tactical CVRSSs will be defined as comprising organisations with at least two depots of 15 vehicles each and/or one depot with at least 25 vehicles. Organisations with a less complex transport problem or depot configurations are unlikely to make full use of CVRS in a strategic-tactical role and, thus, they would be unable to justify its investment costs.

Operational CVRS

Operational CVRS concerns the daily generation of routes at the depot level[2]. Potential users of operational CVRSSs are generally defined according to a minimum size of their vehicle fleet per depot. This criterion is based on the assumption that CVRS used in an operational role enables the vehicle fleet to be reduced by a certain percentage, for example 10%. Therefore, in order to save capital expenditure for at least one vehicle and thus achieve a reasonably short pay-back period for the software's investment costs, a potential distribution site using a CVRSS needs to have at least 10 vehicles. Anything less will not save a full vehicle, and mileage savings alone may not be sufficient to justify the installation of the software.

A further criterion to define potential users of CVRSSs is the complexity of their transport problems in terms of the number of orders and delivery constraints to be considered simultaneously. Once a transport problem exceeds a certain number of orders

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[1] The terms *strategic-tactical* CVRS stands for *strategic* and/or *tactical* CVRS.

[2] See Section 2.3, p. 35f.

and delivery constraints, effective VRS is constrained by the manual scheduler's limited ability to explore all the delivery options[3].

In practice, it is difficult to specify a maximum transport complexity which can be handled manually to a satisfactory degree of effectiveness. However, some indications may be derived from suggestions made in past research and the findings of the current study as shown below:

- According to Sussams [1984] the potential user of CVRSSs should have a fleet of at least five, and preferably more than 20 vehicles per depot.
- Holmes [1989] suggests that, through various means, companies using CVRS techniques should be able to trim at least 10% off their costs. Similar findings have been reported by other empirical studies [ANON, 1993a; Waters, 1986; Murray, 1992; Bodin et al, 1989].
- The software houses interviewed in the current study reported that their clients typically manage to reduce the transport costs of their secondary distribution fleets by an average of 10% to 15% and have at least 8 to 10 vehicles.
- The case studies and survey of the current study have shown that, among those sites where the use of the CVRSS has led to cost savings, the vehicle fleet has been reduced by between 5% and 16%, with an average of 9%[4].

In view of the above evidence, the current research defines the potential market for operational CVRS for use in secondary distribution as containing distribution sites with at least 10 HGVs. This number is considered sufficiently large to justify the software's investment in terms of tangible savings within a reasonable pay-back period of up to three years. Moreover, transport operators running a fleet of 10 HGVs or more are likely to encounter VRS problems sufficiently complex to justify the use of CVRS.

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[3] See Section 2.4, p. 37f.

[4] See Section 3.3.2.2.1.2, pp. 72-73.

4.2.2 Market potential of CVRS technology in the road freight industry

Sussams [1984] reports on a survey undertaken in 1982. This survey defined the potential market for CVRSSs in the UK as comprising approximately 6,000 operators moving certain categories of predominantly customer products up to 50 miles with fleets of more than five vehicles. Unfortunately, Sussams provides no source of reference, which makes the figures unreliable estimates for this research. A useful basis for further analysis, however, is provided by the latest official transport statistics [HMSO, 1988] on the distribution of HGVs by number specified on operator's licence in Great Britain (Table 4.1, column A, B). Given that there were 444,000 vehicles and 130,000 operator's licences in 1987, calculation enables the number of fleets for each class of fleet size to be determined.

A	B	C	D	E
Class of fleet size by vehicles	**Vehicles per class of fleet size**	**Estimated average fleet size per fleet size class**	**Estimated vehicle fleets per fleet size class (col. B : col. C)**	**Estimated vehicle fleets per fleet size class with at least 10 vehicles**
1	60,000	1	60,000	--
1 - 5	99,840	2	49,920	--
6 - 10	57,720	7	8,246	--
11- 20	62,160	15	4,144	4,144
21 - 50	71,040	30	2,368	2,368
51 - 100	44,400	75	592	592
> 100	48,840	150	326	326
Σ	**444,000**		**125,595**	**7,430**

Table 4.1: Survey of market potential of CVRS technology in road transport
(Following HMSO: Transport Statistics Great Britain 1977 - 1987, Table D2, 1988, p. 9)

This calculation is based on the assumption that the average fleet size (Table 4.1: column C) ranges approximately in the middle between the upper and lower limit of each class of fleet size (Table 4.1: column A). The average was lowered slightly for the first three classes (rows one to three) and the fifth class (row five), as there tends to be a greater number of smaller fleets in each vehicle fleet class than there are larger fleets. The calculation results in about 125,600 vehicle fleets (Table 4.1: column D) which are only slightly less than there are operator's licences (130,000). This situation indicates that the actual average fleet size per fleet size class is likely to be smaller than estimated. In fact, the actual number of vehicle fleets should even exceed the number of licences, since some operators have several vehicle fleets per licence. A licence is required for each traffic area (there are nine) in which an operator runs a vehicle fleet. Nevertheless, the established figures appear to point in the right direction and are considered as the best possible estimates. Also, the use of rather low estimates ensures a more conservative approach to determine the market potential of CVRSSs.

The calculation suggests that in 1987 the British road freight industry contained approximately 7,500 vehicle fleets with 10 or more HGVs (Table 4.1: column E). According to non-official information provided by the Department of Transport, the overall structure of the road freight industry by vehicle fleet sizes at the time of the data collection in 1993 was not significantly different from that in 1987.

Nevertheless, to ensure that the number of potential CVRS users is derived from rather conservative estimates, these 7,500 vehicle fleets will be reduced by one third to 5,000 taking account of two factors:

- Firstly, it is likely that over recent years the number of vehicle fleets has decreased due to concentration of market power and the trend towards contract distribution.

- Secondly, it is likely that some of the 7,500 fleets are exclusively used for single or trunking transport operations which are unsuitable for the use of CVRS.

It is interesting to observe that the estimate of 5,000 potential CVRS users established in this study is similar to the above estimate made by Sussams. This enhances the validity of the calculation.

It should be realised that, since companies can have several fleets, there are less than 5,000 companies which are potential users of CVRSSs. However, as companies usually decentralise the use of CVRS with each depot operating a separate CVRSS, the market potential is best specified in terms of vehicle fleets. Estimates given within this research by Britain's suppliers of CVRSSs in 1993 suggest that the market potential for CVRS technology comprises between 1,200 to 2,000 independent companies and 3,000 to 5,000 distribution sites or vehicle fleets.

4.2.3 CVRS market potential in the brewing industry

Evaluating the market potential of CVRSSs in Britain's brewing industry is no easy task. This is mainly due to the industry's complex structure of ownership. Moreover, there are virtually no companies with brewing as their only activity. Nearly all companies involved in brewing have diversified into retailing, distribution or wholesaling of a wide range of products. Also, there is virtually no official information available about the number of existing fleets, by which this research aims to estimate the market potential of CVRS technology. Last, but not least, the development of the brewing industry in this century has been one of amalgamations and take-overs within the sector. This general trend has been reinforced by the regulations established by the Department of Trade and Industry in November 1989, following the Monopolies and Mergers Commission investigation of the industry [Jordans & Son Ltd., 1989]. Therefore, to avoid confusion, this research defines the organisation of Britain's brewing industry as follows:

- A **brewery** is an organisation which has beer production as one of its activities. In addition, such a company may or may not have beer retailing or other diversification.

- A **brewery company** is an organisation which is composed of one or more "breweries". In legal terms, a brewery company is the owner or has the majority control of one or several breweries.

- A **pub brewery** is a brewery company operating a pub with its own brewing facility. A brewing pub usually brews for itself and perhaps a small number of other breweries or retailers.

- An **independent operating centre** is an organisation or part of an organisation with its own decision-making body[5] responsible for the acquisition or implementation of CVRS technology and distribution software in general. In highly centralised organisations the decision to acquire CVRSSs and transportation software in general usually lies with central departments at the head office. In more decentralised organisations, the CVRS acquisition authority may be allocated to regional departments (e.g. management service departments) or local departments (e.g. operational distribution departments of individual breweries). With regard to the potential and current adoption rate of CVRS technology, the classification of organisations in terms of **independent operating centre** is more appropriate than the classification in terms of **brewery companies**.

- An **operational distribution site** is a distribution depot located at a production facility or an external distribution depot from where goods are delivered to customers.

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[5] Previously referred to as "*independent operating centre* with *CVRS decision-making authority*". See Section 1.4.1.1 (p. 13) and 1.4.1.2 (p. 18).

- A **strategic distribution planning site** is an operating centre which carries out strategic or tactical tasks of VRS, for example a management service, logistics, data processing or a similar technical department which tends to be centralised or regionalised.

Because of the lack of data on the number of operational distribution sites and the associated vehicle fleets, it has been decided to initially estimate the CVRS market potential in terms of brewery companies. These are likely to have at least one secondary distribution site with HGVs. An analysis of statistical material obtained from various sources [Hampton Publishing, 1992; Evans, 1992; Jordans & Son Ltd., 1989] identified 234 *brewery companies* located in Britain. These operated approximately 267 *breweries* in 1992.

The findings are supported by data released by Britain's Brewers' Society [Brewers' Society, 1993a] suggesting a slightly larger number of 306 breweries for the same period. The difference of around 39 breweries may be due to difficulties in estimating the number of closed and newly established breweries. Also, the data of the Brewers' Society include breweries of Northern Ireland, while the data of this research relate to Great Britain only.

In order to determine the number of potential users of strategic-tactical and operational CVRS as defined above[6], the 234 *brewery companies* identified were analysed with regard to the size of their vehicle fleets. Excluded from this analysis were the brewery pubs and very small breweries with less than 200 customers, as these were unlikely to operate a vehicle fleet of 10 HGVs or more at any one depot.

A subsequent comprehensive telephone survey identified a total of 42 *brewery companies* and 49 *independent operating centres* with *CVRS decision-making authority*. The latter were operating or controlling approximately 165 *operational distribution sites* with more than 10 HGVs each. The larger breweries or independent operating centres had a further 17 *strategic distribution planning sites*.

The identified total of 49 *independent operating centres* and their associated 165 distribution sites is believed to represent the approximate market potential of operational CVRSSs in the British brewing industry for 1992. Regarding strategic-tactical CVRSSs the market potential is estimated to comprise 17 planning sites (Table 4.2).

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[6] See Section 4.2.1, p. 96.

Organisational Unit	Total	Small Sites (Brewery Pubs)	Sites < 10 HGVs excluding Brewery Pubs	Sites ≥ 10 HGVs
Breweries	267	55	137	75
Brewery companies	234	55	137	**42**
Independent operating centres	241	55	137	**49**
Operational distribution planning sites (depots)	165	not applicable	not applicable	**165**
Strategic-tactical distribution planning sites (logistics, DP functions etc.)	17	not applicable	not applicable	**17**

Table 4.2: Survey of market potential of CVRS technology in Britain's brewing industry 1992

4.3 Use of CVRS technology

4.3.1 Past research

Several past studies have investigated the adoption rate of information technology (IT) used in planning the transport operations of road vehicles (Table 4.3). The software investigated ranged from the simple or rudimentary kind of order allocation software to (usually commercially available) sophisticated CVRSSs based on complex algorithms.

Source	ANON (1977), "Data Processing in the Grocery Trade", Institute of Grocery Distribution (IGD):
Methodology/Response rate	In 1977 questionnaires were sent to nearly 200 companies which were members of the Institute of Grocery Distribution (IGD). The response rate was 50 companies or about 25%.
Company Profile	Sectors (companies) Food & drink (23); non-food grocery manufacturing (3); multiple food retailer (6); co-operation societies (4); freezer food centres (2); variety stores (2); multiple tailor (1); wholesaler (5); transport & storage company (2); non-identified companies (2: one retailer, one manufacturer) Size The companies were a mixture of medium to large organisations. The exact company profile was not mentioned.
Results	30% of respondents were using data processing in vehicle scheduling.
Source	Wright, D. and Cross, A. (1985), "Information Technology and the Freight Transport Industry", Cranfield Institute of Technology, Centre of Transport Studies (CTS)
Methodology/Response rate	In 1985 a questionnaire was sent to 900 firms sampled from the licensing records of the East Midlands Traffic Commissioners. The survey was preceded by a pilot study in 1984, which included a shorter questionnaire distributed to 400 firms. The response rate for the main survey was 10% and over 20% for the pilot survey.

Table 4.3: Past research on the adoption of IT in planning the transport operations of road vehicles 1977 - 1988

Company Profile	A proportionally high number of responses was obtained from large firms, i.e. those owning more than 10 vehicles.
Results	45% of respondents were using routing systems; 20% were using scheduling systems; 50% were using load planning.
Source	Peters, M. and Doganis, R. (1987), "Information Technology in Delivery Control", Polytechnic of Central London: Transport Studies Group (TSG)
Methodo-logy/Res-ponse rate	In 1984 research details were sent to 250 Companies. Companies favourably disposed towards the research were interviewed over a 12 months period starting January 1985. Companies were further selected according to a minimum fleet size of 10 vehicles per depot. In all 30 companies involved in road freight distribution, both own-account and third party hauliers were studied.
Company Profile	All companies were involved in some form of multi-drop/collection distribution with the following profile. Sectors (companies) a) Own-account operators: food products (6); soft drinks, beers, wines and spirits (5); white and brown goods (4); miscellaneous, e.g. pharmacy, heating, fuels etc. (9) b) Third party operators: dedicated carriers (3); consolidating carriers (3) Fleet size (companies) 11 - 25 vehicles (4); 25 - 50 vehicles (3); 51 - 75 vehicles (7); 76 - 100 vehicles (1); >100 vehicles (11); third party fleets (4). Depot networks utilised (companies) 1 depot (6); 2 - 5 depots (10); 6 - 10 depots (6); 11 - 15 depots (4); >15 depots (3); one third party haulier operated a dedicated service from the consignors depot.
Results	43% of companies were using round planning software systems
Source	Parkin, J. and Probert, S. (1987), "Information Technology in Road Haulage and Distribution", Focus of Physical Distribution, Vol. 6, No. 8
Methodo-logy/Res-ponse rate	In 1987 a questionnaire was sent to 900 distribution companies in West Yorkshire. 100 or 11% of the companies responded.
Company Profile	No information available
Results	12% of respondents were using (interactive) vehicle scheduling packages
Source	Langley, C. et al (1988), "Microcomputers as a Logistics Information Strategy", IJPD&LM, Vol. 8, No. 6
Methodo-logy/Res-ponse rate	In-depth telephone interviews were held with 100 logistics executives selected at random from the membership roster of the Council of Logistics Management.
Company Profile	Sectors (companies) Food and beverage (20); chemicals and plastics (10); pharmaceuticals, drugs, and toilet preparations (10); department stores/retail (10); other manufacturing/merchandising (50)
Results	56% of respondents used computers for vehicle routing of which 38% used software run on microcomputers.

Table 4.3 (continued): Past research on the adoption of IT in planning the transport operations of road vehicles 1977 - 1988

Source	KPMG Management Consulting: The Management of Information Technology in the Distribution Industry, 1991
Methodo-logy/Res-ponse rate	In 1991 questionnaires were sent to 500 members of the Institute of Logistics and Distribution Management. Return rate: no information available.
Company Profile	Sectors (in % of respondents) Manufactures (9%); retailers (16%); food and drink (16); contractors (25%); distributors (34%). Company size by turnover (in % of respondents) 0 - 10 £ million (32%), 10 - 100 £ (32%), >100 £ million (34%)
Results	Less than 20% of respondents had vehicle based (software) systems

Table 4.3 (continued): Past research on the adoption of IT in planning the transport operations of road vehicles 1977 - 1988

Overall, the studies' findings are mixed. The adoption of IT in planning the transport operations of road vehicles varies from 12% to 56% as presented in the summary Table 4.4:

Source	IGD [1]	CTS [2,7]	TSG [3]	P&P [4]	L. et al [5]	KPMG [6]
IT in planning the transport operations of road vehicles	30%	45%* 20%** 50%***	43%	12%	56%	20%

[1] IGD = Institute of Grocery Distribution, 1977: Scheduling software.

[2] CTS = Centre for Transport Studies (Cranfield Institute of Technology), Wright, D. and Cross, A., 1985: Routing software (*) and scheduling software (**), load planning software (***).

[3] TSG = Transport Studies Group (Polytechnic of Central London), Peters, M. and Doganis, R., 1987: Round planning (routing and scheduling) systems.

[4] P&P = Parkin, J. and Probert. S., 1987: Scheduling packages.

[5] L et al = Langley, C. et al, 1988: Routing software.

[6] KPMG = KPMG Management Consulting, 1991: Vehicle based (software) systems

[7] The mentioned data of the CTS '85 study were taken from the study's seminar report no. 1 (Introduction). It is not fully clear whether the results refer to the pilot study or the main survey involving 400 firms and 900 firms respectively. (Seminar report no. 6 mentions that "vehicle routing and scheduling packages are used by around 9% of firms". This figure appears to contradict the above findings mentioned in seminar report 1 and it is not clear to what sample or population it refers. It should be noted that Parkin and Probert [1987, p. 22] and Waters [1990, p. 28] quote the CTS study, but this time "vehicle scheduling" was used by 6% of organisations. Various attempts were made by the author of this research to clarify the situation, unfortunately without success. A solution to the confusion may lie in the CTS study's reports no. 4 and 5 which, however, were no longer available.)

Table 4.4: Summary of past studies on the adoption of IT in planning transport operations of road vehicles 1977 - 1988

Differences in the studies' use of nomenclature and methodology prohibit a valid comparison of the studies' findings. For instance, none of the studies provides a clear definition of what kind of transport software has been analysed.

- The study of Wright and Cross (*CTS*) is the only one to differentiate its findings into *vehicle routing*, *vehicle scheduling* and *load planning*, with the latter presumably referring to combined *vehicle routing and scheduling*. However, it remains unclear what type of software is actually covered by the terms used. An adoption rate of sophisticated vehicle routing and scheduling (*load planning*) or CVRSSs by 50% would seem rather high, but possible, as far as large organisations are concerned.

- The low adoption rate of 12% identified in the study of Parkin and Probert (*P&P*), its use of the term *vehicle scheduling* and the fact that the study's appendix gives a listing of software differentiated into vehicle routing and vehicle scheduling systems, give justification for the belief that the authors have predominantly investigated the use of sophisticated CVRS technology.

Also, it is not clear whether the findings are representative for the whole population from which the surveys' underlying samples have been drawn. Potential bias may be given by an over-representation of companies with specific characteristics, for example large companies.

- There is some evidence to suggest that this may be the case in the survey of Peters and Doganis (*TSG*). Measured by the number of vehicles and depots the companies involved tended to be medium to large, rather than small companies.

- This issue most likely also applies to the study of Langley et al (*L. et al*), which is based on interviews of logistics executives. Such executives usually come from large organisations.

- The *P&P* study and the *CTS* by Wright and Cross provide limited information on the profile of the investigated companies.

- In contrast, the study of KPMG Management Consulting (*KPMG*) gives a clear picture of the size of the responding companies. However, it fails to indicate the response rate achieved.

Finally, the studies generally do not give any information on the ownership of the IT concerned. Some companies may possess and operate the software on their own. Other companies may have used the software via a consultant in an one-off operation.

Two further studies on the use of commercially available and thus sophisticated CVRSSs are worth mentioning. The previously quoted article of Sussams [1984] estimated the market of sophisticated CVRS packages amounting to 2% of 6,000 or 120 operators (fleets). In 1989, Britain's leading supplier of CVRSSs estimated that there were 120 companies using sophisticated CVRSSs in the UK [Holmes, 1989]. The potential market of CVRS technology was predicted to comprise another 900 companies thus suggesting an adoption rate of approximately 12%.

4.3.2 Use of CVRS technology in the road freight industry

The overall inconsistent findings of past research on the use of CVRS technology highlight the need for a new comprehensive survey as presented below:

4.3.2.1 Adoption rate of CVRS technology

A survey of all suppliers of CVRSSs in Britain was carried out in January 1993, using a mailed questionnaire and in-depth interviews. The survey determined the number of CVRSSs sold to private and public organisations in Britain and the number of sites where the systems were installed until 1993[7] (Table 4.5: Column A).

The CVRS installations is shown as a total (including strategic-tactical and operational CVRSSs; Table 4.5: Column B). CVRSSs used in an operational role at the depot level are listed separately (Table 4.5: Column C). The figures are also shown reduced conservatively by 20% to allow for organisations and distribution sites which have ceased using purchased CVRSSs. This may have occurred because of organisations going out of business, contracting out their transport operations or because of CVRS failures caused by inadequate software and/or implementation.

A	B	C
Independent Organisations using CVRS	**Operational + strategic-tactical CVRS installations**	**Operational CVRS installations only (depots)**
338	**865**	**668**
270 (338 - 20%)	**692 (865 - 20%)**	**534 (668 - 20%)**

Table 4.5: The use of CVRS technology in the road transport industry 1993

7 See Section 1.4.1.2 ("Survey of CVRS suppliers"), p. 16.

Since this survey aims to evaluate the adoption rate of CVRS technology in relation to depot operators, the figures on CVRS used in an operational role (534 installations at depots) represent the basis for further analysis.

Comparing the 534 distribution sites which were using sophisticated CVRS technology in 1993 with the estimated market potential of approximately 5,000 operators or distribution sites, the adoption rate amounts to about 11% for the same period. It is interesting that most of the suppliers of CVRS technology interviewed confirmed this figure as a realistic estimate.

4.3.2.2 Use of CVRS technology by sectors of commerce

The use of CVRSSs is spread throughout various sectors of the road freight industry (Figure 4.1). The statistics are based on information provided by eight out of nine CVRS suppliers. Only one supplier with approximately 70 customers (companies) was unable to specify the distribution of its customers by sectors of commerce. Therefore the data refer to 268 organisations instead of 338 (reported) organisations. However, it can be assumed that the organisations not included in the statistics are spread over the sectors of commerce proportionally to the 268 other organisations.

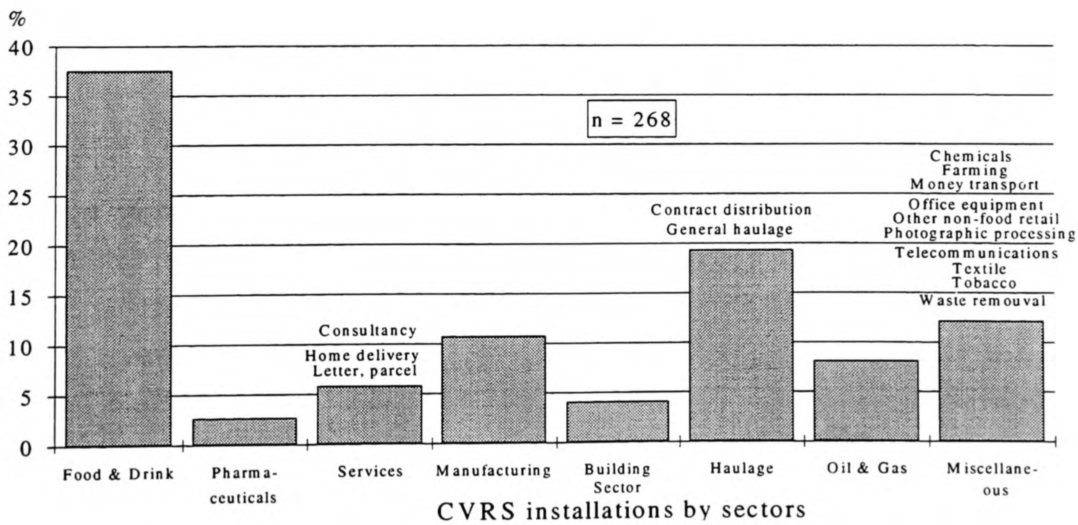

Figure 4.1: Use of CVRS technology by sectors of commerce

The great majority (more than 80%) of all users are own-account operators or a mixture of own-account operators and sub-contractors, with the food and drinks sectors representing the largest group. Less than 20% of users are road carriage providers.

4.3.2.3 Future use of CVRS technology

Diffusion of CVRS technology

Within the CVRS market, potential buyers or users differ in their speed of acceptance of new technology. This process of product penetration through a market is commonly referred to as "diffusion of innovation" [Kotler, 1994; Loudon and Della Bitta, 1993; Baker, 1992; Wilson and Galligan, 1992; Webster, 1991; Mahatoo, 1985; Midgley, 1977].

It is important to distinguish between the concept of diffusion and that of adoption. *Diffusion* of CVRS technology is a group process concerning the spread of the use of the software through the market in time from one organisation to another. By contrast, *adoption* of the CVRS technology relates to the acceptance and continued use of the software by individual organisations. Hence, diffusion and adoption are inextricably connected in that "the diffusion process necessarily involves the adoption process of many individuals over time" [Loudon and Della Bitta, 1993, p. 272]. Similarly, Gatignon and Robertson [1985, p. 850] suggest that the "diffusion pattern at the social system level is an outcome of the distribution of individual adoption processes".

Past research has identified several factors influencing the diffusion of innovations. The relevant factors considered in the current research can be classified into (1) intrafirm factors, (2) product characteristics and (3) supply side competitive effects. The factors are briefly outlined below[8]:

Intrafirm factors: Following Rogers [1962[9]] the rate of diffusion is influenced by intrafirm factors described by a classification of the buyers within the diffusion process into five groups as shown in Figure 4.2. The classes differ in terms of organisational structure (company size, availability of risk capital, level of centralisation etc.) and individual differences (age, education, attitudes etc.) of participants involved in the buying decision process.

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8 A detailed discussion of these factors would go beyond the scope of this research. For further detail see Webster, 1991, p. 169f.

9 See also Kotler [1994, p. 348f], Loudon and Della Bitta [1993, p. 275f], Webster [1991, p. 165f], Engel et al [1986, p. 542f].

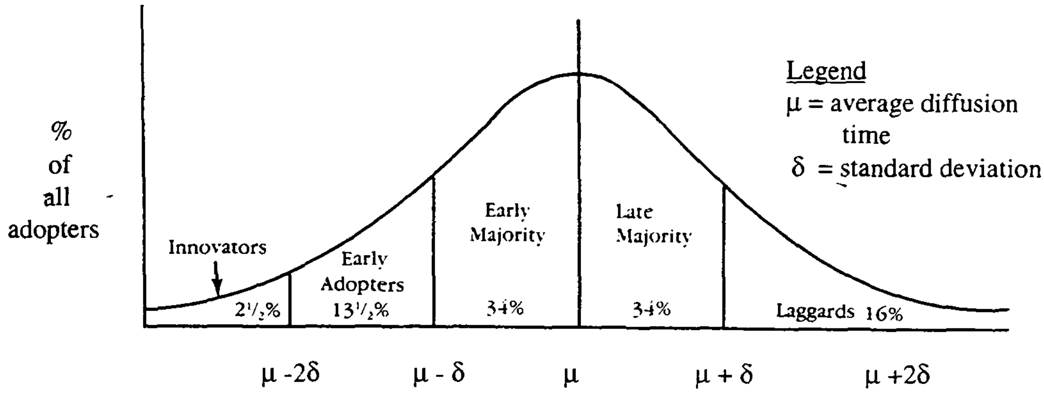

Figure 4.2: Rogers' categorisation of adopters based on the time of diffusion of innovation

(Source: Adopted from Rogers, 1962, p. 162)

Because it is generally difficult to characterise individuals or organisations according to several buyer categories as suggested by Rogers, Midgley [1977] proposes a simplified and, so he feels, more practical as well as more easy to use categorisation. His model divides buyers into innovators (16% of all buyers) and late adopters (84% of all buyers). Like Rogers, Midgley constructs his classification model using the normal distribution. At the same time he highlights that "measurement of innovators has been shown to be distribution free, and hence the categorisation scheme should not force the innovators to be 16 percent of the adopting population whatever the shape of the empirical distribution" [Midgley, 1977, p. 55].

Similarly, Peterson [1973], Mahatoo [1985] as well as Mahajan et al [1990a] argue that the assumption of all new products being subject to a normal distribution diffusion pattern is questionable. In their comprehensive review of past diffusion research Gatignon and Robertson [1985, p. 861] conclude that the categorisation of innovator profiles according to the normal distribution "is only a heuristic that might be useful; it is not based on theoretical grounds with a clear-cut assignment of individuals to categories."

In summary, the selection of criteria used in determining categories of innovators has been subject to considerable controversy and various different models have been suggested. A useful suggestion worth mentioning has been made by Robertson [1971] arguing that the classification boundaries should be placed according to distinct changes in the characteristics of the innovators. This concept is also suggested by the established diffusion model of Bass [1986, 1969] which does not incorporate the assumption that the diffusion process necessarily follows a normal distribution. Also, the model avoids an arbitrary division of the adopter distribution into a fixed number of categories[10].

Product characteristics: There are six product characteristics which appear to influence the diffusion of an innovation [Midgley, 1977; Engel et al, 1986; Loudon and Della Bitta, 1985; Webster, 1991] including (1) relative advantage, (2) compatibility, (3) complexity, (4) trialability, (5) observability, and (6) cost:

- Relative advantage is the extent to which an innovation is perceived to provide greater advantage over the previous products or procedures to be replaced by the innovation.
- Compatibility is the extent to which an innovation is consistent with existing values and past experiences or procedures.
- Complexity refers to how difficult an innovation is to understand and to use.
- Trialability is the extent to which an innovation may be tried on a limited basis.
- Observability (or communicability) refers to consciousness of an innovation or the extent to which it can be observed by other organisations or potential adopters.
- Cost refers to the amount of financial resources required to obtain, implement and use an innovation.

Supply side competitive effects: The rate and level of diffusion of an innovation are positively influenced by the following factors [Robertson and Gatignon,1986]:

- Competitive intensity among suppliers;
- Reputation of suppliers as a group;
- Vertical co-ordination between suppliers and customers;
- Standardisation of an innovation;
- Research and development expenditure by the suppliers; and
- Marketing activity by the suppliers.

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[10] For further discussion of criteria for determining adopter categories see Mahajan et al [1990a], Anderson et al [1987] and Midgley [1977].

While research has focused on which factors affect the diffusion process, the mechanisms of the process have so far not been described with any great precision. This view is shared by Mahatoo [1985, p. 151 - 152] who concludes: "Although theorizing on the mechanism of diffusion is sparse, a number of models have been developed for predicting the diffusion of new products; that is, predicting the number of consumers likely to accept a new product and the time it will involve. The models do not contain any behavioural constructs. Essentially they are concerned with the relationship between time and new product sales".

The closest to a treatment of the mechanisms involved is the "trickle-down theory" dealing with women's fashion[11]. This theory has been replaced by the "two-step" hypothesis suggesting that "diffusion takes place horizontally from opinion leaders to others within the same group" [Mahatoo, 1985, p. 150].

The process, as suggested by the two-step hypothesis and the diffusion models of Rogers as well as Midgley and other researchers regarding innovators (which tend to be large and venturesome organisations with high levels of risk capital) can also be observed in the British brewing industry. In fact, among the first organisations to adopt CVRS technology within this industry were three of the country's leading brewing groups which are generally considered as opinion leaders within the industry.

Product life-cycle of CVRS

The prediction of product life-cycles is related to diffusion theory [Baker, 1992]. There are two types of analytical support for modelling life-cycles [Urbain and Star, 1991]:

- Aggregate diffusion modelling based on available past sales data for initial rather than repeat purchases; and
- Customer flow modelling used in the absence of past sales data; that is, for products prior to introduction or products very early in the life-cycle.

In **aggregate diffusion modelling** the basic analytical support procedure is based on collecting accurate sales and product histories. Moreover, the modelling requires estimates of the total number of customers who will ever buy the innovation and probability estimates concerning initial and subsequent purchase of the innovation. The

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11 For further detail see Miller et al [1993], Gatignon and Robertson [1989] and Mahatoo [1985].

model assumes that, as the cumulative number of past buyers (i.e. users of the innovation) increases, the probability of new purchase increases for those individuals or organisations which have not yet bought. The key mechanism in this process is that "intensifying word-of-mouth communication and rising social acceptance increase the probability of purchase as diffusion of innovation takes place" [Urbain and Star, 1991, p. 106].

Customer flow modelling simulates the flow of the individual consumers from one stage in the buying process to another. The inputs required to implement such a flow model are estimates on the fraction of individuals flowing between stages, "i.e. from various information levels to awareness of the product to exposure to it at retail to involvement in interpersonal communication" [Urbain and Star, 1991, p. 112]. Mathematical programming is usually required to allow for effective simulation of various flow scenarios with alternative sets of probability estimates. Similarly to the above aggregate diffusion model one of the key mechanisms of flow models is informal or word-of-mouth communication significantly fuelling the diffusion process.

It needs to be highlighted that the current research does not intend to develop and empirically validate a comprehensive and accurate aggregate diffusion model, customer flow model or product life-cycle of CVRS technology[12]. This is due to the lack of sufficient data to accurately estimate the models' parameters, in particular the probability estimates. Also, the generation of a meaningful CVRS diffusion model requires extensive mathematical programming which would exceed the scope of the investigation[13]. Finally, the CVRS life-cycle is extremely long. This entails a high level of uncertainty regarding future events such as technological and economic change or governmental regulations in road transport.

Nevertheless, on the basis of *trend analysis* this research predicts the diffusion of CVRS in the total road freight industry in terms of the number of installations for the near future (1994 - 1998). The calculation uses the accumulated figures regarding CVRS installations sold until 1986 and annual sales figures from 1986 to 1993. Overall, a quadratic function seems to fit the observations better than an alternative linear or

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12 Instead, the empirical research focuses on the adoption process of the software within individual companies which will be the subject of Chapter 6.

13 For further detail, see Miller et al [1993], Mahajan et al [1990a], Mahajan et al [1990b], Böker [1987], Mahajan and Muller [1979].

exponential function. This is shown visually by the fit of the curve (Figure 4.3) and the generally lower error estimates of the quadratic function[14].

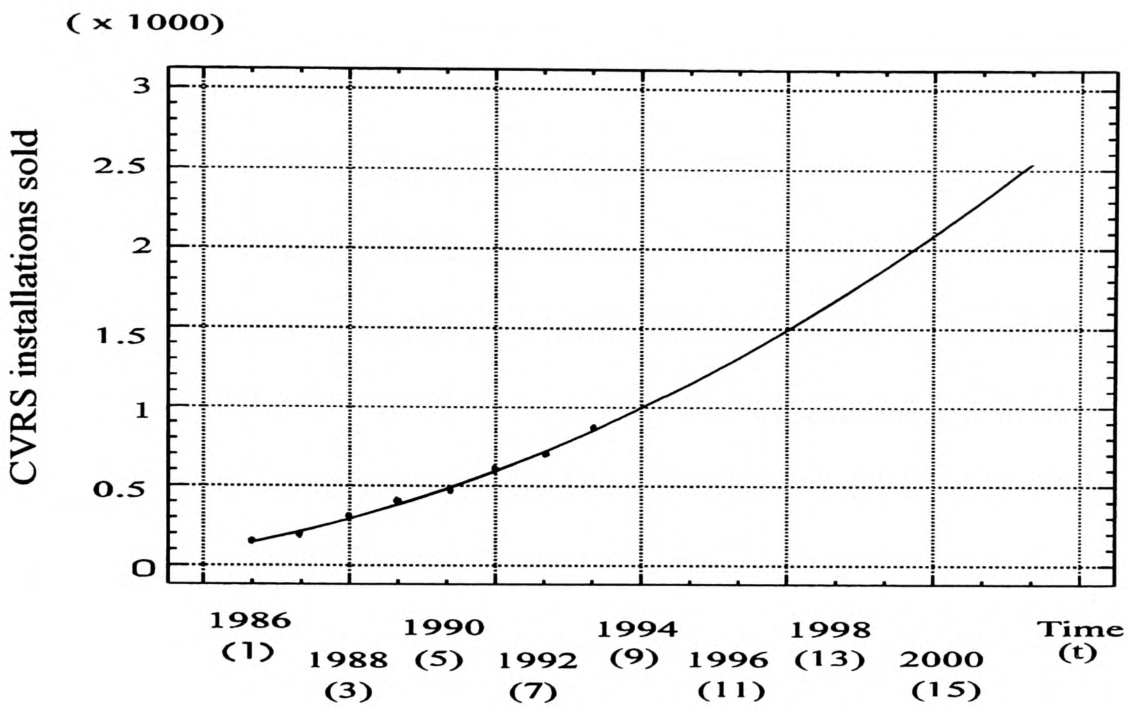

Figure 4.3: Fitted model of forecasting sales of CVRS installations 1994 - 1998

Since the uncertainty about the predictions grows with a change in time, trend predictions made on the basis of the trend function are limited to a period of five years. The calculation predicts an increase of around 95% from 865 CVRS installations in 1993 (total sales of CVRSS installations indicated by software suppliers) to 1,682 installations in 1998. This figure corrected by approximately 20% for CVRSSs used exclusively in a strategic-tactical[15] role and a further 20% for system abandonment as explained above would equal about 1,000 CVRS installations used in an operational role. This figure would represent an adoption rate of 20% on the basis of 5,000 potential users or vehicle fleets.

Following the concept of the *product life-cycle* [Kotler, 1994; Kotler and Armstrong, 1991], the apparent low adoption rate of CVRS technology and the assumed (positive)

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[14] Trend function: $90.3571 + 51.7024 * T + 5.44048 * T^2 = 1{,}682$; the projected year 1998 represents the 13 period (t). For further details on the error estimates of the alternative linear, quadratic and exponential functions see Table A3-1 (Appendix 3), p. A-34.

[15] The terms *strategic-tactical* CVRS stands for *strategic* and/or *tactical* CVRS.

quadratic function suggest that the software is currently at the beginning of its "growth phase" (Figure 4.4). The life-cycle shown illustrates past and future sales of CVRS installations. It also indicates the underlying rate of the software's diffusion. The basic structure of the life-cycle from the software's first introduction until the end of this century is supported by the market background data available which will be discussed in relation to some of the above diffusion factors:

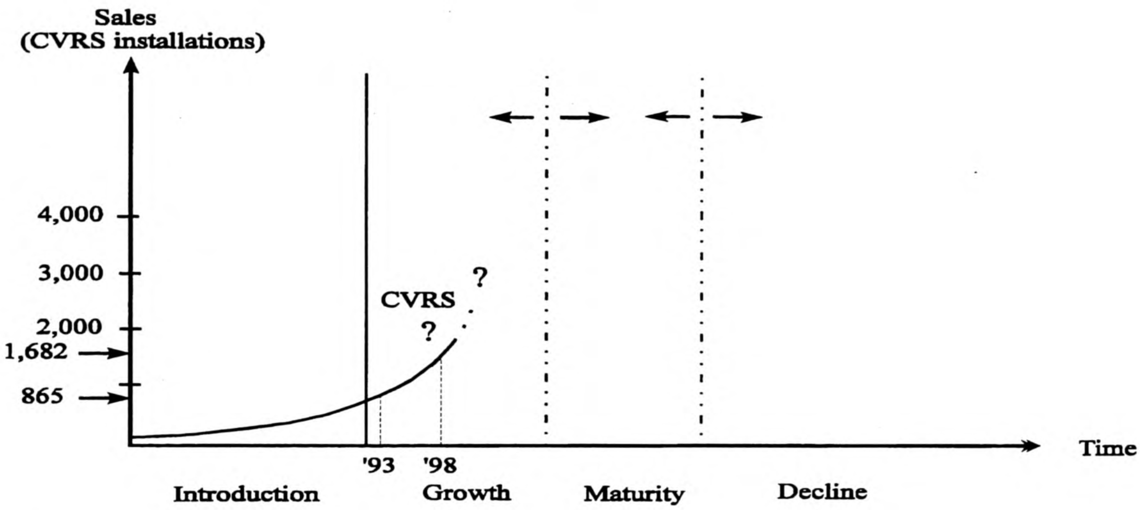

Figure 4.4: Product life-cycle of CVRS technology

Introduction phase:

The early CVRSSs became available on the British market in the late sixties (*Routemaster* package). For many years the market development was sluggish which may be explained as follows:

- Relative advantage: Past studies suggest that many companies fail to perceive CVRS as providing greater advantage to their manual VRS technique or use of allocation software [Wright and Cross, 1985]. The credibility of CVRS technology suffers particularly in its early days from the, sometimes spectacular, reported failures of the software in distribution operations [Polak, 1988].

- Compatibility: The degree of compatibility of CVRS with a firm's manual VRS technique or use of allocation software is generally low. In fact, CVRS technology generates routes differently from the manual schedulers. In particular, the early CVRS systems have severe technical limitations such as the lack of accurate road databases; that is, routes are generated on the basis of Euclidean distances rather than actual distances between two points.

The first generation of CVRS packages also have conceptual weaknesses in that they lack sufficient interactive features. The packages are designed to replace the manual schedulers rather than assisting them and thus combining the speed as well as the accuracy of computing power with the human planners' special knowledge. Hence, there are compatibility problems between product design and the end user.

Further constraints result from the computer hardware used which is limited in terms of both data processing capacity and speed. There are severe limitations on the number of orders to be considered simultaneously, the effective handling of road network data (travel times and distances) and the speed of the route generation procedure.

Also, given the cross-sectional nature of the VRS function, CVRS affects routines and procedures in the transport function (e.g. familiar route structures, drivers' pay schemes) and related areas such as order processing and warehousing[16].

- Complexity: The early CVRS technology is complex as well as relatively difficult to understand and to use.

- Trialability: Most early CVRS suppliers offer potential users the opportunity to test their package. However, this may involve payment of substantial fees for renting the software and hardware. Most importantly, costs are bound to arise for the consultancy service involved, including user training. In addition, effective testing of CVRS technology is extremely time-consuming, requiring extensive human resources. Also, many potential buyers may refrain from testing the software, because this tends to interrupt existing work procedures and may lead to considerable irritation as well as confusion among the work force.

- Observability: Unlike consumer products such as fashion and vehicles, the practical use of early CVRS technology is not directly observable by other organisations or potential adopters.

- Cost: Early CVRS technology is comparatively expensive in terms of initial investment costs, implementation and maintenance[17]. A further significant constraint of diffusion in the early days of the technology is likely to have been the high investment costs of the computer hardware.

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[16] See Section 2.2, p. 33f.

[17] See Table A6-1: "List of CVRS suppliers" (Appendix 6), p. A-38.

- Supply side competitive effects: Initially, CVRS technology is distributed by relatively few software houses. These companies are small and specialised software houses with generally limited financial and human resources. As a result, their marketing activity is rather limited.

Growth phase:

A driving force behind the apparent increase in the diffusion rate of CVRS installations since the late eighties (as indicated by the increasing gradient of the trend curve) may be explained by a change in some of the diffusion factors as discussed below:

- Relative advantage: Individuals and organisations have become generally more aware of benefits of IT and, thus, more willing to use it. At the same time, the quality of CVRS technology has made significant advances which is likely to have increased the perceived relative advantage of the software.

- Compatibility: Due to major technical improvements CVRS technology has become more compatible with a firm's requirements in CVRS. The latest generation of CVRS packages includes a variety of features which quite accurately model an organisation's actual distribution environments and associated constraints. Some of the most spectacular advances have been made in the area of the software's integrated road database, for example the ability to consider actual driving times and distances, one-way streets and driving speeds according to the time of the day. Also, some packages allow simultaneous multi-depot planning. Finally, using standard software interfaces, integration of CVRS technology with other software systems has become more convenient and efficient.

- Complexity: Technically, the complexity of CVRS technology continues to rise. In terms of the user interface, however, the software has become significantly easier to handle. In particular the availability of a graphical display of the routes, usually on the underlying digitised or scanned road network, makes the route generation process more transparent and thus more easily comprehensible.

- Trialability: The suppliers of CVRS technology have become more aware of the potential buyers' need to test the software. The basic problem of limited trialability due to the above factors remains, i.e. CVRS technology is complex and cannot simply be tested without major investment of time, effort and thus financial resources. One useful means to accommodate "hands-on experience" with the software is the provision of free or low cost training courses as practised by some of the suppliers. Also, costs for renting the computer hardware are usually no longer an obstacle for testing the software, as most organisations tend to have the required facilities readily available.

- Observability: The publication of company case studies at conferences and, most importantly, in trade magazines has rendered the practical use of CVRS technology more observable by other organisations. This process is expected to have strongly contributed to an overall awareness of the availability as well as the benefits of the software and thus promoted its diffusion in the market. A strong influence on the rate of diffusion is also expected to have resulted and to continue to result from the non-marketer or informal word-of-mouth communication [Mahatoo, 1985]. This information source is "most important when the product is perceived to have substantial social, psychological or economical risks involved in its purchase" [Engel et al, 1986, p. 535]. These product characteristics apply to CVRS technology.

- Cost: In absolute terms CVRS software remains comparatively expensive technology. However, with an increased knowledge of the software's considerable benefits, costs are believed to have become somewhat less of a constraint for the software's diffusion. The diffusion has without doubt also benefited from the drastic reductions in the costs of computer hardware.

- Supply side competitive effects: In the late eighties the supply side of the British CVRS market has been gradually extended by both successful new British and established suppliers in the United States. It can be expected that a larger number of suppliers with successful packages and the consequently increased overall marketing activity has contributed to an increase in the number of CVRS systems sold.

4.3.3 The use of CVRS technology in the brewing industry

4.3.3.1 Use of strategic-tactical CVRS

CVRS was used in a strategic-tactical[18] role by 6 of 17 (35%) potential users. One distribution planning site (Brewery-D) was using the software on an irregular basis,

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[18] The terms *strategic-tactical* stands for *strategic* <u>and/or</u> *tactical*.

mainly for planning tasks such as the nomination of delivery days or the impact of changing levels of order frequencies (customer service) on transport costs. The software was initially acquired for the planning of depot locations. However, at the time of data collection of the current study the company operated only one depot. The other five distribution planning sites were central management service departments and logistics departments within large brewery groups, each of which operated several secondary distribution depots[19].

Three out of the 6 sites started using CVRS in a strategic-tactical role prior to using it for daily planning. The principal consideration behind this was to get a feeling for the effectiveness of CVRS technology and thus estimate the software's potential benefits in operational planning. Also, the sites wanted to estimate the most likely impacts of operational CVRS on their organisations. Particular points of interest were the effort required for data collection, the length of the implementation period, the software's impact on work routines and whether the workforce was ready to accept such new technology.

Approximately 6 to 9 months after the implementation and successful use of strategic-tactical CVRS, two sites (Brewery-A, Brewery-D) also implemented a CVRSS for daily planning at their associated distribution depots. The third site (Brewery-I) had just implemented a strategic-tactical CVRSS during the data collection of the current research. However, the site indicated plans to use CVRS for daily planning at its attached distribution depots in the near future. The remaining three sites (Brewery-B, Brewery-C, and Brewery-G) had decided to use CVRS initially at the operational depot level before implementing it for use in a strategic-tactical role.

The above fashion of using CVRS was also reported by suppliers of CVRSS technology suitable for strategic-tactical planning. Between 20% and 30% of mainly medium to large organisations operating CVRS in an operational role have initially conducted strategic-tactical CVRS.

4.3.3.2 Use of operational CVRS and order allocation software

The VRS techniques used by the 49 independent operating centres are shown in Figure 4.5. The combined figure of sites using operational CVRS and those using order

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[19] See Table 1.1, p. 15.

allocation software amounts to 71%. It is interesting to note that this figure is close to the estimates made by the *CTS*, *TSG*, and *L. et al* studies outlined above[20] which estimated the use of software in VRS to range between 43% and 56% in 1985 to 1987. Allowing for a certain increase in the adoption rate between those studies and the current research, an adoption rate of 71% in the overall use of computers in VRS appears to confirm the trend.

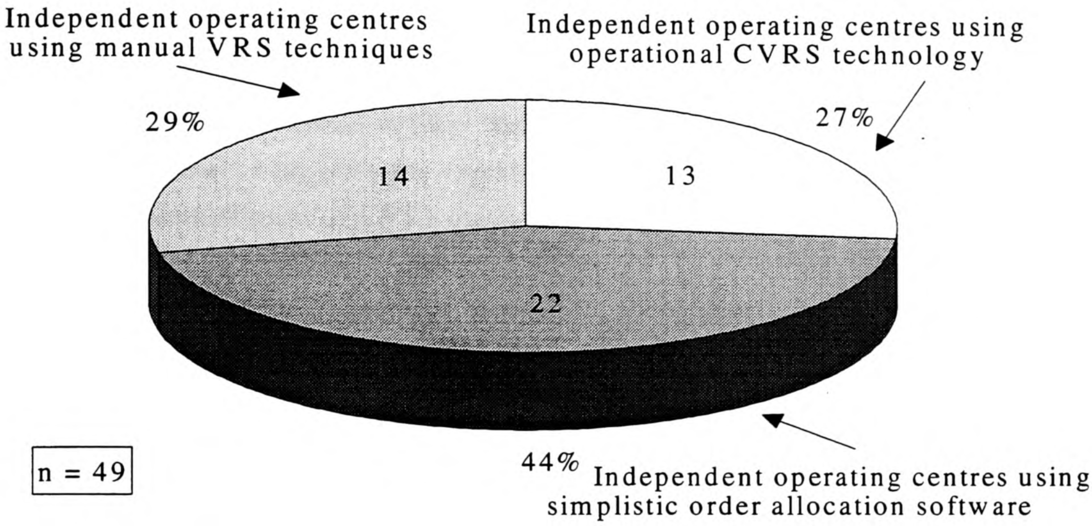

Figure 4.5: Techniques of operational VRS in the brewing industry 1992

In terms of operational distribution sites or secondary distribution depots, the user rate of operational CVRS is 67 out of approximately 150 sites (45%). The great majority, i.e. 70% or 46 of the 67 sites are allocated to only three independent operating centres. Therefore, judged on the basis of operational distribution sites, there is a tendency to overestimate the actual number of CVRSSs used. A more reliable indicator for the adoption rate of operational CVRS technology, therefore, is the number of *independent operating centres* as shown in Figure 4.4 above.

4.3.3.3 Future use of CVRS technology

Among the 36 independent operating centres not using operational CVRS technology at the time of the data collection, 7 sites indicated an intention to implement such software

[20] See Table 4.4, p. 104.

in the near future, that is within the next three years. If these plans were put into practice, the adoption rate of operational CVRS technology would increase from 27% (13 independent operating centres) at the time of data collection to 41% (20) independent operating centres) by 1995. It is interesting to note that all those 7 sites intending to implement CVRS technology were users of simplistic *order allocation software* at the time of data collection.

Looking at the previous VRS methods of organisations already using CVRS technology suggests a similar picture. One third or 4 sites had been using computerised order allocation software previously. However, among those 4 sites, which started using CVRSSs in the past five years or later than 1987, all had been using order allocation software. This situation suggests that experience with order allocation software is a good predictor for potential users of CVRS technology.

Hence, using order allocation software appears to be a transition phase towards the use of sophisticated CVRS technology. Initial experience with order allocation software may prepare companies for the use of CVRS technology in terms of the technological and organisational maturity required. According to the software suppliers, many potential CVRS users are interested in the software, but feel that they are "not ready" for it. Typical constraints are the absence or reorganisation of existing distribution software systems such as sales order processing or warehouse and stock control software. Of equal or, perhaps greater, importance is that initial experience with order allocation software may prepare individuals psychologically for the subsequent transition phase towards sophisticated CVRS technology.

Also Cooper and Jessop [1983, p. 53] have recognised the apparent need for simple versions of CVRS technology facilitating the smooth change from fully manual VRS to sophisticated CVRS. The authors propose the idea of "'intermediate' packages which are designed around the current practices of individual companies. The emphasis would be to have the computer fit the customer rather than the other way around".

4.4 Summary

CVRS adoption rate in the road transport industry

Regarding the road transport industry as a whole, approximately 11% (534 out of 5,000) of the operational distribution sites were using CVRS technology in 1993. The sites were allocated to approximately 270 independent organisations. It is important to realise that these findings are based on secondary data, that is data provided by the HMSO and the CVRS suppliers. Moreover, certain assumptions are made regarding a likely reduction in the number of fleet operators between the publication (1987 of HMSO's transport statistics) used for determining the number of fleet operators and the date of the current research. It is also assumed that 20% of organisations which have purchased CVRS technology abandoned its use.

Provided that the data supplied and assumptions made are correct, the findings give strong support to *hypothesis 2a*: The availability of CVRS technology has not led to the degree of usage in the road transport industry as a whole in 1993 that its efficiency would seem to justify.

The apparent lack of CVRS system penetration or the "CVRS user gap" becomes even more evident by comparison with typical traditional distribution software, such as sales order processing, sales analysis, payroll and stock control systems. Previous studies have shown that these systems are standard applications used by between 70% and 90% of road transport operators [KPMG, 1991; Langley et al, 1988; Peters and Doganis, 1987; Wright and Cross, 1985], (Figure 4.6).

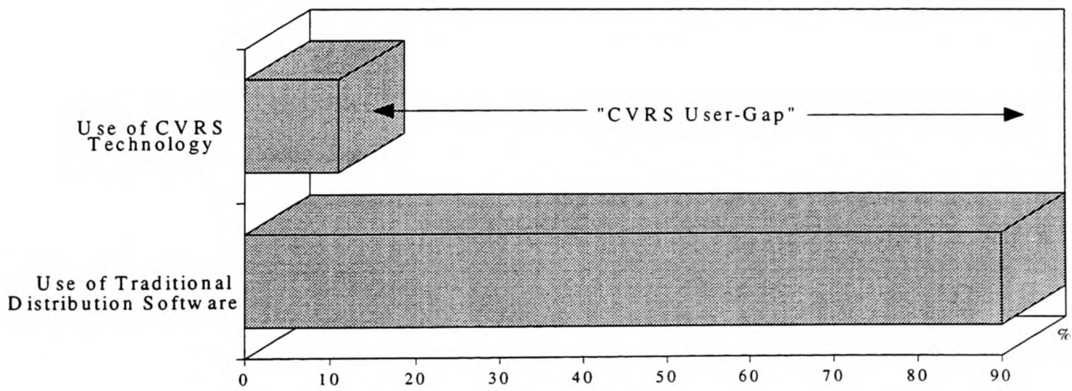

Figure 4.6: Use of distribution software in the road transport industry

CVRS adoption rate in the brewing industry

With respect to the brewing industry, the adoption rate of CVRS technology is substantially higher than the average of the road transport industry. In 1992, 35% (6 out of 17) strategic distribution planning sites were using CVRS in a strategic-tactical role. Somewhat lower was the adoption rate of CVRS used in an operational role. In terms of independent operating centres, the adoption rate was 27% (13 out of 49) sites. The comparatively high adoption rate of CVRS technology in the brewing industry may be explained by several factors as outlined below:

Pioneers of CVRS technology

The brewing industry, together with the drinks and food industry in general, has been one of the first sectors to adopt CVRS technology as shown by several case studies [Evans and Norback, 1985; Zielinski, 1984; Rothhaar, 1980; Mowat, 1978; Foulds et al, 1977]. In fact, some of the early CVRS packages have been developed from experience gained in the brewing industry.

Concentration of market power in the brewing industry

Unlike perhaps any other sector of commerce in Britain and even the whole of Europe, the British brewing industry has gone through a continuous process of concentration of market power [Brewers' Society, 1993a; Jordans & Son Ltd., 1989]. The number of UK breweries decreased from 6,447 at the beginning of the century to as little as 306 in 1993. At just under 37,000,000 barrels the annual production of beer, however, remained roughly the same between both points in time [Brewers' Society, 1993a, 1993b]. Hence, the British brewing industry is composed of a small number of large breweries. As large companies usually favour the use of IT, the relative adoption rate of IT is higher in such concentrated markets compared to markets with a low concentration, being composed of many but small companies. This appears to be the case regarding CVRS technology which is used by 4 out of the industry's 5 largest companies.

Transport costs

The relatively high adoption rate of CVRS technology in the brewing industry is partly a reflection of the high costs of its transport operations. These are characterised by the movement of large weights and volumes within a competitive, consumer-driven and, therefore, highly restrictive distribution environment in terms of short order lead times, high delivery frequencies and tight time windows[21]. It is not surprising, therefore, that transport costs in the brewing industry, as for the food, drinks and tobacco sector as a whole, are the highest in all sectors of industry. With an average of 50%, transport costs constitute by far the largest element of a company's total distribution costs [ILDM,

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[21] See Section 2.5 ("Principal operating parameters"), p. 45f.

1992]. The cost pressure of transport appears to have been a driving force behind the use of CVRS technology in the brewing industry.

Structure of the transport problem

The brewing industry's VRS problem in secondary distribution involves *depot-bound multiple deliveries* and/or *collections* of goods in a restricted distribution environment. The latter is characterised by an overall constant customer circle, regular customer order patterns but strong fluctuations in order quantities. This particular structure makes the industry's VRS problem suitable for solution by current CVRS technology[22].

CVRS User-gap

Comparing the adoption rate of VRS technology with other distribution software used by 46 of the independent operating centres investigated, the apparently high adoption rate of CVRS still turns out to be rather low (Figure 4.7). Consequently, the "CVRS user-gap" is also present in the brewing industry, which gives strong evidence to support *hypothesis 2b.* This suggests that the availability of CVRS technology has not led to the degree of usage in the brewing industry in 1992 that its success would seem to justify.

Figure 4.7: Use of distribution software in the brewing industry 1992

22 See Section 2.5, p. 40f.

Chapter 5: CVRS Model in the Organisational Context

5.1 Introduction

The two previous Chapters have demonstrated that CVRS is successful technology, but only used by a relatively small number of organisations. The following Chapters 6 and 7 will aim to identify:

- the factors which explain individual organisations' adoption of CVRS technology; and

- the factors which ensure CVRS success in organisations using CVRS technology.

To achieve these objectives this research has developed a *CVRS model in the organisational context.* The model functions as a "framework of thought"[1] [Kubicek, 1975a, 1975b] enabling pairs of research variables to be related to one another. The model will be presented in this Chapter with the statistical techniques used to validate it.

The basic structures of the *CVRS model in the organisational context* have been derived from literature on organisational behaviour (OB), organisational buying behaviour (OBB) and information systems (DSS/MIS). The notion "in the organisational context" refers to the model's characteristic of focusing on organisational aspects rather than technical aspects of CVRS technology.

Once the basic structures of the model was developed in terms of the relevant <u>general</u> classes of OB, OBB and DSS/MIS-variables such as **individual differences**, **user attitudes** and **user satisfaction**, the latter were specified with a view to CVRS. Moreover, the general variables were extended, along with some CVRS-specific variables such as CVRS **operators' performance** and **drivers' performance**. This process was guided by the qualitative data obtained from the previous case study and expert interview research.

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[1] Original German term: "gedanklicher Bezugsrahmen".

The *CVRS model in the organisational context* is composed of two separate sub-models (Figure 5.1). This characteristic explains why the model is subsequently referred to in the plural as "*CVRS models*" including the:

- ***CVRS adoption model*** addressing the factors associated with the adoption of CVRS; and
- ***CVRS success model*** addressing the factors associated with the success of CVRS.

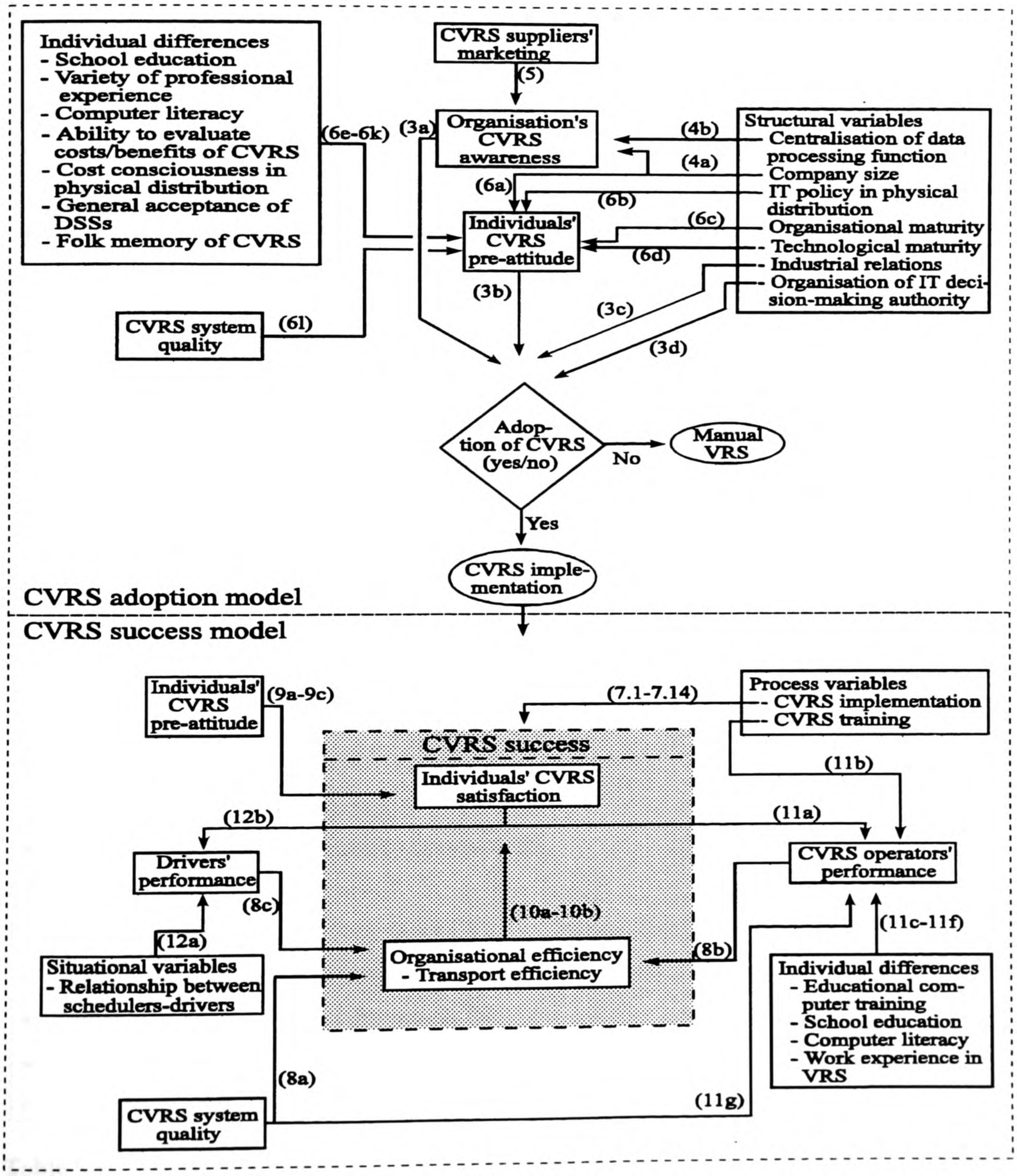

Figure 5.1: CVRS model in the organisational context

The relationships between variables of the models illustrated in Figure 5.1 are expressed in terms of hypotheses, each of which is designated by a number. Tables 5.1 and 5.2 give an overview of the hypotheses which can be related to Figure 5.1 by their corresponding numbers.

Hypotheses relating to the *CVRS adoption model*
***Hypotheses 3a - 3d*:** The adoption of CVRS technology is positively associated with the potential users': • awareness of the software available (*hypothesis 3a*); • pre-attitude towards the software (*hypothesis 3b*); • industrial relations (*hypothesis 3c*); and • organisation of decision-making authority for IT in transport (*hypothesis 3d).*
***Hypotheses 4 a - 4b*:** The awareness of CVRS technology is positively associated with the potential users': • company size (*hypothesis 4a*); and • centralisation of the data processing or equivalent service function (*hypothesis 4b*).
***Hypothesis* 5**: The software suppliers' marketing activity has not led to a significant awareness of CVRSSs available.
***Hypotheses 6a - 6l*:** The pre-implementation attitude towards CVRS technology is positively associated with the potential users': • company size (*hypothesis 6a*); • IT policy in physical distribution (*hypothesis 6b*); • organisational maturity (*hypothesis 6c*); • technological maturity (*hypothesis 6d*); • school education (*hypothesis 6e*); • variety of professional experience (*hypothesis 6f*); • computer literacy (*hypothesis 6g*); • ability to evaluate costs and benefits of CVRS technology (*hypothesis 6h*); • consciousness of costs in physical distribution (*hypothesis 6i*); • general acceptance of DDSs (*hypothesis 6j*); • folk memory of CVRSS failures (*hypothesis 6k*), and • experience with CVRS system quality (*hypothesis 6l*).

Table 5.1: Hypotheses relating to the *CVRS adoption model*

Hypotheses relating to the *CVRS success model*
Hypothesis 7: CVRS success is related to a preponderance of favourable forces in each phase of the implementation process. (**Note**: This hypothesis includes 14 sub-hypotheses - 7.1 to 7.14 - which will be presented in Section 7.2)
Hypotheses 8a - 8c: Organisational efficiency of CVRS users is positively associated with the: • CVRS system quality (*hypothesis 8a*); • CVRSS operators' performance (*hypothesis 8b*); and • Drivers' performance (*hypothesis 8c*).
Hypotheses 9a - 9c: The • managers' satisfaction with CVRS (*hypothesis 9a*); • schedulers' satisfaction with CVRS (*hypothesis 9b*); and • drivers' satisfaction with CVRS (*hypothesis 9c*); is positively associated with their attitude towards CVRS prior to the software's installation.
Hypotheses 10a - 10b: The • managers' satisfaction with CVRS (*hypothesis 10a*); and • schedulers' satisfaction with CVRS (*hypothesis 10b*); is positively associated with the impact of CVRS on organisational efficiency.
Hypotheses 11a - 11g: The CVRS operators' performances are positively associated with their: • CVRS satisfaction (*hypothesis 11a*); • specialised training on the software - "CVRS training" (*hypothesis 11b*) • educational (college/in-house) computer training (*hypothesis 11c*); • school education (*hypothesis 11d*); • computer literacy (*hypothesis 11e*); • work experience in VRS (*hypothesis 11f*); and • CVRS system quality (*hypothesis 11g*).
Hypotheses 12 a -12b : The drivers' performances are positively associated with their: • relationship with the CVRS operators (*hypothesis 12a*); and • satisfaction with CVRS (*hypothesis 12b*).

Table 5.2: Hypotheses relating to the *CVRS success model*

5.2 Statistical analysis

The associations suggested in the above *CVRS models* will be tested statistically using the quantitative data collected from own-account fleet operators involved in secondary distribution in the British brewing industry and from the CVRS suppliers[2]. The data were analysed using the Statistical package STATGRAPHICS Plus, version 6.0[3].

The following Sections 5.2.1 to 5.2.5 will outline the techniques used for analysing the quantitative data and some critical aspects to be considered in the analysis and interpretation of associations between variables.

5.2.1 Hypothesis testing

Selected and achieved samples

In total 49 brewery *operating centres with CVRS decision-making* authority were identified. For 47 of them the survey is based on selected samples of 100%. For the remaining two operating centres (which are large national breweries) the selected samples were taken at *random*: 17 out of 30 (55%) depots for one brewery and 11 out of 17 (65%) depots for the other.

Due to non-response, the achieved samples are typically 80% and, for some hypotheses tested, up to 93%.

Need for significance tests

Though at a comparatively low level, *sampling errors* are present, as the achieved samples are below 100%. To be able to justify the use statistical hypothesis testing or *significance tests* it needs to be ensured that the achieved samples allow reliable and valid estimates of corresponding population parameters to be established. This condition is met by the appropriate manner by which the samples were selected as outlined above.

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2 See Section 1.4.1.2 ("Survey of current, potential and past users of CVRS in the brewing industry"), p. 17f.

3 Supplied by Manugistics Incorporation, USA, 1992.

Moreover, the possibility of *bias* occurring from non-responses can be safely excluded as substantiated below[4]:

- The principal reason for non-response was the potential respondents' lack of time due to work pressure. In fact, most organisations, including the non-responding ones, expressed strong interest in the study.

- The non respondents represent organisations with average characteristics in term of transport problems, company size and organisational structure.

The measurement instruments (questionnaires, structured interview guides) have been designed and administered with great care. Nevertheless, the data will probably be affected by *measurement error* which almost certainly occurs randomly. There is no evidence that this has occurred in a systematic manner due to, for example, maliciously false responses.

Considering the relatively large achieved samples, the interpretation of the results is extremely conservative and thus safer than in most other surveys which rely on much smaller samples and associated higher levels of sampling error. At the most extreme, the practice adopted in the current study may result in rejecting hypotheses which in fact are true. However, this risk is considered to be less serious than the risk of accepting hypotheses which are in fact wrong; that is, have only occurred as a result of error.

It may be argued that there is a need for modifying the standard significance test by a correction factor thus accounting for the low levels of sampling error. It was felt safer, however, to refrain from the use of such correction factors thus interpreting the sample statistics in a rather conservative manner.

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[4] It shall be noted that most surveys use selected samples representing only small fractions of their underlying populations. As a result, *significance tests* or *inferential statistics* are used to judge the validity of generalising from the achieved samples to the total underlying populations [Tull and Albaum, 1973]. For this to be a valid procedure, the achieved samples need to allow reliable and valid estimates (statistics) of the corresponding population parameters to be established. This is achieved by selecting the samples at *random* and excluding the possibility of *bias* in case of non-response.

In comparison, the sampling procedure applied in the current research is somewhat unusual in that the selected samples are relatively large in percentage terms of their underlying total populations. Nevertheless, the use of *statistical significance tests* is valid and necessary, because the achieved samples do not cover the total underlying populations. Moreover, the achieved samples provide reliable and valid estimates of the corresponding population parameters and *bias* from non response has been excluded.

The following paragraphs will outline the general procedure of statistical hypothesis testing using significance tests:

The statistical testing of hypotheses is carried out by formulating a *null hypothesis* as the principal hypothesis which is compared with a corresponding *alternative hypothesis*. The null hypothesis specifies the parameter values to be tested. The word "null" indicates that no causal association or difference between variables exists. The null hypothesis will not be rejected unless the sample results are clearly inconsistent with it, in which case the alternative hypothesis will be accepted [Kaztmier and Pohl, 1984].

The decision on whether the null hypothesis can be accepted or rejected is made on the basis of certain rules. Whatever decision rule is adopted, there is some chance of reaching an erroneous conclusion about the population parameter of interest [Newbold, 1991]. One error ("Type I error") that could be made is the rejection of a true null hypothesis. The probability of rejecting the null hypothesis when it is true is α which, referred to as a percentage, is said to be the ***significance level*** of the test. The other error ("Type II error") that could be made is to fail to reject a false null hypothesis[5].

Three commonly used *significance levels,* which represent the accepted probabilities of rejecting a null hypothesis that is true, are the 1%, 5% and 10% levels. Following Bortz [1993] the *significance levels* used in the current research are specified as follows:

- $p \leq 1\,\%$ highly significant result
- $p \leq 5\%$ significant result
- $p \leq 10\%$ moderately significant result

For instance, *correlation analysis* may suggest at the 5% *significance level* ($p \leq 5\%$) that there is a positive association between two variables, for instance the level of training on CVRS ("**CVRS training**") and the scheduler's ability to operate a CVRSS ("**CVRS operator's performance**"). Hence, the null hypothesis that there is no association between **CVRS training** and **CVRS operator's performance** would be rejected in favour of the alternative hypothesis suggesting that there is a relationship between the variables. In doing so, one would accept a 5% probability that the null-hypothesis is rejected despite it being true, that is, that there really is no association between the variables tested.

[5] Regarding the Type II error, see Newbold, 1991, p. 349.

For convenience, the current research formulates all hypotheses as alternative hypotheses. Hence, if an association between a pair of variables is found to be statistically significant at any of the above three levels, this implies that the assumed null hypothesis is being rejected and the alternative hypothesis is being accepted.

Strictly speaking, hypotheses referring to associations between variables are usually tested statistically using *correlation analysis*. If *ANOVA* or the *Kruskal-Wallis* test are used, a hypothesis really needs to be phrased in terms of differences between variables. However, for convenience and to provide a consistent presentation of hypotheses, the current research always phrases hypotheses in terms of associations between variables. Also, the statistical results will usually be interpreted in terms of associations. Therefore, if hypotheses are tested with *ANOVA* or the *Kruskal-Wallis* test, the differences found will be considered as either positive or negative associations.

5.2.2 Statistical techniques

The relationships suggested in the *CVRS models* of the current research are multivariate in nature; that is, individual variables are expected to be related to one or more other variables in the research models. Hence, the models ideally suggest the use of multivariate analysis, such as the *multiple regression model*, *analysis of variance* (*MANOVA*) or *discriminant function analysis*. Such multivariate or integrative models attempt to account for a greater proportion of variance among the variables investigated than do the generally less comprehensive uni- and bivariate tests. In addition, they typically demonstrate on the basis of their underlying assumptions how the variables under study are related to each other [Steers, 1975].

The data collected in this study do not comply with some of the requirements of multivariate analysis [Bortz, 1993; Manugistics, 1992; Newbold, 1991; Joseph, 1990; Roscoe, 1975; Willemsen, 1974; Tull and Albaum, 1973]. Therefore, the *CVRS models* will be validated by the use of predominantly univariate and non-parametric bivariate procedures. This will ensure that the findings obtained are statistically valid and reliable. The violated requirements of multivariate or parametric procedures concern two major issues:

- Firstly, there is insufficient evidence to support the *assumption of normality* (i.e. the assumption that the residuals or differences between the estimates and the actual data, are normally distributed) for certain variables.

- Secondly, most of the data have low orders caused by their ordinal and nominal scaling. Data with low orders are commonly considered to be unsuitable for parametric testing [Bortz, 1993; Manugistics, 1992; Newbold, 1991; Joseph, 1990; Roscoe, 1975; Willemsen, 1974; Tull and Albaum, 1973].

In two areas non-parametric bivariate findings are complemented by multivariate procedures:

- Firstly, *construct validity* of combined measures or indices[6] is evaluated using *factor analysis* which relies on the *normality* assumption [Jolliffe 1986]. Hence, the findings obtained from *factor analysis* are <u>indicative</u> as opposed to firm <u>evidence</u> for the existence of *construct validity*. However, the findings of *factor analysis* are always supported by findings provided by further non-parametric testing.

- Secondly, with view to the future use and further development of the proposed *CVRS models*, Chapter 8 demonstrates the potential of multivariate analyses for selected areas of the models. Due to the above limitations induced by the data available the multivariate findings are not conclusive. Hence, these findings are considered as indications only rather than firm evidence.

The non-parametric techniques, including *factor analysis*, used in the major part of the analyses are presented below:

Kruskal-Wallis test

The *Kruskal-Wallis test* is a non-parametric version of the *one-way ANOVA*. As is typical of non-parametric testing, the procedure looks at median values rather than means which are more affected by outliers. Hence, it is employed if there are strong grounds to suspect that the parent distribution may be markedly different from normal. Like many non-parametric tests, the *Kruskal-Wallis test* is based on ranks of the sample observations [Manugistics, 1992; Newbold, 1991].

For instance, one may want to assess whether the groupings **schedulers** and **drivers** (samples of two populations differentiated by a *dichotomous* classification variable) differ in the level of satisfaction with CVRS (subsequently referred to as "**CVRS satisfaction**"). The variable **CVRS satisfaction** may be measured by an index based on

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6 See Section 1.4.2.2 ("Testing validity"), p. 31f.

average scores of several indicators each of which has a *semantic differential seven-point scale*. The populations are pooled together and their values ranked in ascending order using the averages of adjacent ranks in the case of ties, as shown in Table 5.3. The test is based on the sum of ranks.

Schedulers' CVRS satisfaction	Rank	Drivers' CVRS satisfaction	Rank
6.4	15.5 (tie)	2.4	4
6.2	14	4.2	10
6.5	17	2.0	3
3.7	8	3.1	6.5(tie)
6.4	15.5 (tie)	2.9	5
4.7	11	1.3	2
5.9	13	1.2	1
6.7	18	3.1	6.5 (tie)
5.4	12	4.1	9
Rank sums:	124		47
Average ranks:	13.78		5.22

Table 5.3: Example of the Kruskal-Wallis test

Now, the *null hypothesis* to be tested is that the two population medians are the same. Without outlining every single arithmetical step of the test in further detail, a test statistic is calculated which is compared against a *table for the Kruskal-Wallis tes*t (for small sample sizes) or a *chi-square distribution* (for large sample sizes)[7]. In the current example, the test conclusions are that the population medians are clearly different at the 1% significance level. The average ranks of schedulers are higher than the average ranks of drivers. Hence, the null hypothesis can be rejected, suggesting that the schedulers have a significantly different level of **CVRS satisfaction** from the drivers.

Note that in the above example the null hypothesis is also rejected using the parametric *ANOVA*. This, however, would impose the *assumption of normality*.

Spearman's rank correlation coefficient

The *Spearman's rank correlation coefficient* (in the tables of the subsequent statistical analyses referred to as *"RCC")* is the non-parametric version of the *Pearson Product Moment correlation coefficient*. As a non-parametric procedure it does not rely on the

[7] For further details see Newbold, 1991, p. 648f; Manugistics, 1992, p. K19f (Statgraphics Plus 6.0 Reference Manual).

normality assumption. Like the above *Kruskal-Wallis test,* the coefficient is based on ranks of observation from two samples.

The *Spearman's rank correlation coefficient* ("*r*") can be used to test the linear association between a pair of random variables. The coefficient "*r*" indicates the strength and direction (+ or -) of the association as follows:

- $r = +1.0$ total positive, linear association
- $r = 0.0$ no linear association
- $r = -1.0$ total negative, linear association

For instance, one may want to test whether individuals' understanding of and experience with computing ("**computer literacy**") is associated with their pre-implementation attitudes towards CVRS ("**CVRS pre-attitudes**"). Hence the null hypothesis is that there is no association between the two variables. The calculated correlation coefficient is compared with a test statistic based on the sample size and the significance level. On the basis of this comparison it is decided whether the null hypothesis can be rejected.[8]

As with the *Kruskal-Wallis test*, the parametric *Pearson Product Moment correlation coefficient* can substitute for the equivalent *Spearman's rank correlation coefficient,* provided the data comply with the *assumption of normality.*

Cronbach Alpha coefficient

The *Cronbach Alpha coefficient* is used to assess the *reliability* of measurement[9]. It is a function of the number of indicators relating to a single concept, dimension or sub-dimension and the inter-correlations among the indicators. The coefficient can take values between zero and one. There is no theoretical minimum value which the *Cronbach Alpha coefficient* has to assume in order to highlight the *reliability* of a measure. However, the commonly specified lower limit ranges between 0.6 and 0.8 [Bargl, 1994; Schnell et al, 1993; Churchill, 1979]. This research uses the strict lower level of 0.8.

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8 For further details see Newbold, 1991, p. 466f.

9 See Section 1.4.2.2, p. 30f.

Factor analysis

Factor analysis is a statistical data reduction technique which can be applied to a set of variables or indicators. The researcher wants to discover which variables in the set form coherent subsets that are relatively independent of one another. Correlating variables which are largely independent of other subsets of variables are combined to form *factors*. These factors are understood to reflect underlying processes which have led to the correlations among variables [Tabachnick and Fidell, 1989].

Schnell et al [1993] and Churchill [1979] differentiate between the exploratory and the confirmatory *factor analysis. Exploratory factor analysis* is used without having previously specified the hypotheses concerning the results of the analysis. *Confirmatory factor analysis*, in contrast, aims at assessing whether the exactly specified hypotheses about the expected results can be supported by the data.

Having commenced with clearly defined hypotheses, the current quantitative research uses *confirmatory factor analysis. Factor analysis* is used to test *construct validity* of combined measures consisting of more than one indicator; that is, to evaluate whether indicators measure the same concept, dimension or sub-dimensions to which they relate[10]. Indicators with high factor loading are shown to be part of the same factor.

For instance, the **managers' CVRS satisfaction** concept used in the *CVRS success model* is measured by seven indicators as will be shown later. Carried out on the basis of the managers' responses to each of the indicators *factor analysis* aims to confirm that the seven indicators effectively measure the same object, that is **managers' CVRS satisfaction**. This is the case if *factor analysis* identifies a high factor loading for each of the indicators which means that exactly a single factor can be extracted.

There is no theoretical minimum loading which an indicator needs to take in order to be considered for factor interpretation. Generally speaking, the higher the loading, the more the indicator is a pure measure of the factor. As a rule of thumb, Tabachnick and Fidell [1989] suggest a minimum loading of 0.3 and above. Bortz [1993] claims a minimum of 0.6 and more. Comrey [1973] suggests that a loading in access of 0.71 is excellent. Following Bortz, this research uses 0.6 as the minimum factor loading.

The indicators which are part of a factor, are combined to form an *index* which is obtained from averaging individuals' responses to the indicators. The use of indices

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[10] See Section 1.4.2.2, p. 31f.

reduces the amount of statistical analysis required for the subsequent testing of variables in hypotheses.

Correlation of items with total scores

Correlation of items with total scores (subsequently referred to as "*total score correlation*") is also used for testing *construct validity*[11]. As suggested by its name, the technique calculates correlations between single indicators and the sum of all remaining indicators. A measure is understood to have *construct validity* if the calculated correlations are high overall.

For instance, if in the above example the seven indicators of **managers' CVRS satisfaction** have overall high correlations, then this means that the concept investigated satisfies the criterion of *construct validity*.

5.2.3 Causality

The basic nature of the current research is *cross-sectional* as opposed to *longitudinal*; that is, data were collected at a single point in time [Fink and Kosecoff, 1985]. As a result, individual variables cannot be manipulated while others are controlled for. For this reason, in conjunction with the above limitations of the non-parametric statistics, it is not possible to provide statistical evidence on causality of relationships. Similarly, Tabachnik and Fidell [1989, p. 127] suggest: "Demonstration of causality is a logical and experimental, rather than statistical, problem".

Nevertheless, the models' predictions of relationships between variables assume one or two-way causal relationships, provided these are meaningful and plausible. Additional support for the assumed causal relationships is provided by the qualitative findings of the in-depth case studies.

Occasionally, it is also possible to reason *a priori* on the nature of the relationships. This is the case if one variable has to precede another in time. For instance, individuals' pre-attitude towards CVRS ("**CVRS pre-attitude**") must precede their satisfaction with the software ("**CVRS satisfaction**") after implementation. Hence, if a significant association

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[11] See Section 1.4.2.2, p. 31f.

is found between the two variables, then it can at least be safely suggested that **CVRS satisfaction** cannot cause **CVRS pre-attitude**.

While in this particular case the direction of the causal relationship is clear, it still remains unclear whether **CVRS satisfaction** is not caused by one more other independent variables which may or may not be included in the model. In fact, Bortz [1993] suggests that most bivariate correlations derived in social research are such that both variables are influenced by one or several other variables. Similarly, Tabachnik and Fidell [1989, p. 127 - 128] suggest: "An apparent strong relationship between variables could stem from many sources, including the influence of other, currently unmeasured variables".

Hence, **CVRS satisfaction** may be caused by the amount of cost savings allowed for by the software ("**organisational efficiency**") rather than **CVRS pre-attitude**. If this is the case, the association between **CVRS pre-attitude** and **CVRS satisfaction** is not based on causality. It is also possible that **CVRS satisfaction** is influenced by both **CVRS pre-attitude** and **organisational efficiency**.

5.2.4 Dependent and independent variables

In this research a *dependent variable* stands for an object of analysis (e.g. **CVRS operators' performance**), which is influenced by another object of analysis referred to as an *independent variable* (e.g. **CVRS training**), [Bortz, 1993]. Both terms are used for convenience to indicate the *expected* causal relationship between variables as opposed to suggesting the *existence* of such causality.

5.2.5 Formation of indices

Indices

If dimensions or sub-dimensions are measured by more than one indicator, these indicators are averaged as indices [Schnell et al, 1993; Bryman, 1988; Lazarsfeld, 1958]. For instance, the **managers' general pre-implementation attitude of CVRS technology** dimension ("**general CVRS pre-attitude**") is measured by three indicators

(C-5, 7, 9[12]). The respondents' ratings given to each of these indicators are averaged to form a **general CVRS awareness index**.

Indices are also formed if responses to complex indicators need transformation. For instance, the measurement of individuals' awareness of CVRS ("**actual CVRS awareness**") is based on an indicator concerning the respondents' knowledge of the existence, features and prices of the CVRSSs available on the market. The quantification of the respondents' **actual CVRS awareness** is defined by a numerical system or index according to the number, price etc. of CVRSSs known. The index will be outlined in further detail later[13].

***Overall* indices**

Following Lazarsfeld [1958] and Bryman [1988] an *overall* index is defined as an aggregation (sum or average) of several dimensions or sub-dimensions of a concept. The current research generally refrains from forming *overall* indices. The reason for doing so is to avoid a loss of information which is bound to occur from the aggregation of individual or different dimensions and sub-dimensions.

Also, *overall* indices tend to be difficult to interpret. For instance, combining all twelve sub-dimensions of the **pre-attitudes towards the quality of the CVRS in relation to individual requirements in physical distribution** dimension (Table 6.3[14]) into an *overall* index would obscure the impact of single sub-dimensions on dependent variables which are the subject of analysis.

Moreover, the use of overall indices requires the numerical weighting of those dimensions or sub-dimensions and associated indicators which are considered particularly important. As outlined earlier, such numerical weighting has certain disadvantages which overall render the technique unjustifiable for the current research in most situations[15].

A few exceptions to the decision not to use *overall* indices in this research are made, where the use of such indices is more meaningful than individual dimensions. For example, the *overall* index **company size** is composed of the four dimensions:

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12 The full phrasing of the indicators can be viewed in Appendix 1, p. A-1f.

13 See Table 6.6, p. 152.

14 See Table 6.3, p. 150.

15 See Section 1.4.2.1 ("Multidimensionality"), p. 28f.

- **annual sales in £**;
- **annual delivery volume in metric tonnes**;
- **number of daily orders;** and
- **number of HGVs**.

Chapter 6: Factors Associated with the Adoption of CVRS

6.1 Introduction

This Chapter investigates the reasons for the low adoption rate of CVRS technology or the "CVRS user gap" which is apparent in the brewing industry. The investigation focuses on factors influencing individual organisations' decisions to adopt or reject CVRS technology[1].

Section 6.3 will present for analysis some potentially relevant independent variables, which are believed to be associated with the adoption of CVRS. Subsequently, the variables have been incorporated within a set of hypotheses which will be tested with the help of the survey data collected in the brewing industry.

Sections 6.4 and 6.5 will extend the scope of the investigation. Those independent variables, which in Section 6.3 will turn out to be significant in influencing the *CVRS decision makers'* choice to adopt CVRS will be analysed in relation to their cause. Hence, variables which in Section 6.3 are treated as independent variables will then be treated as dependent variables. The aim is to identify those independent variables which explain the then dependent variables.

The relationships between the variables investigated are illustrated in Figure 6.1 showing the *CVRS adoption model.*

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[1] *Adoption* of the CVRS technology relates to the acceptance and continued use of the software by individual organisations. By contrast, *diffusion* of CVRS technology as discussed earlier is a group process concerning the spread of using the software from one organisation to another throughout the market. See Section 4.3.2.3, p. 108f.

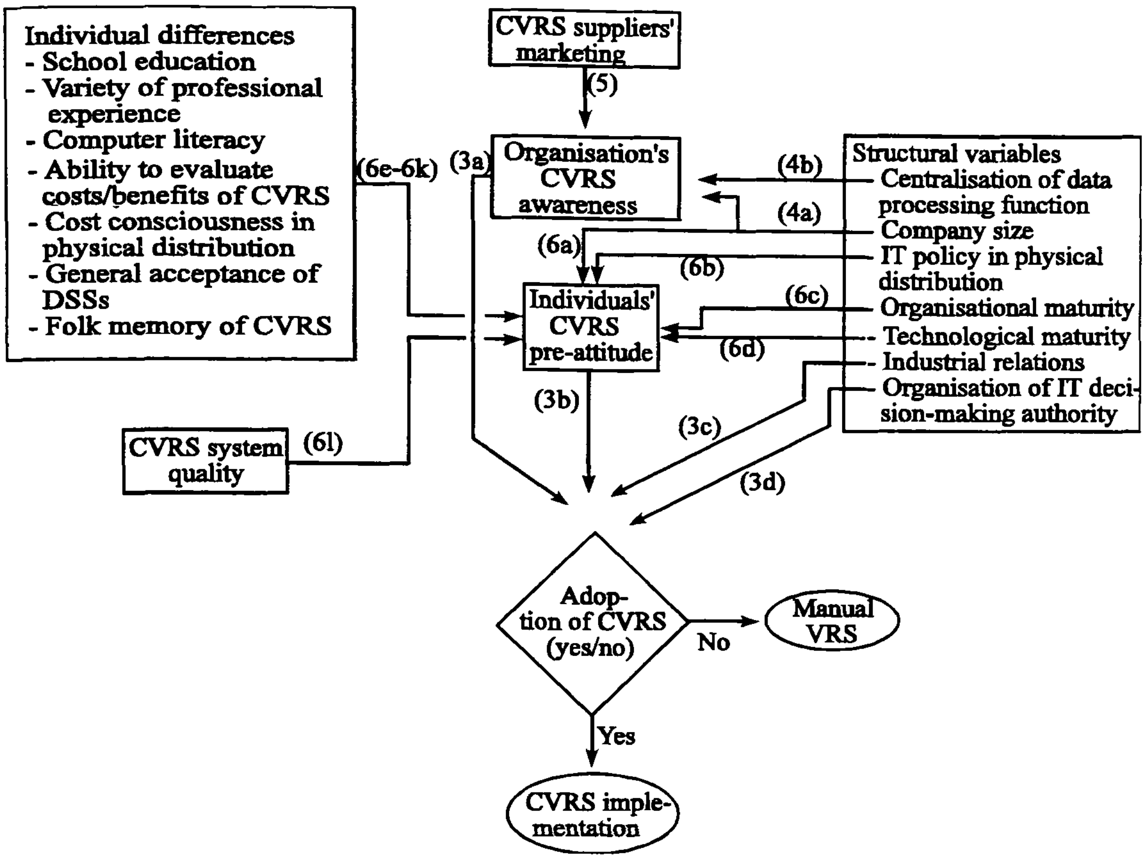

Figure 6.1: CVRS adoption model

The model is consistent with past academic research directly concerned with a better understanding of organisational buying behaviour (OBB). The past studies can be classified into three areas as suggested by Wind and Thomas (1980).

- the buying centre;
- the organisational buying process; and
- the factors influencing the organisational buying centre and buying process.

The buying centre

There is widespread agreement over the concept of the organisational "buying centre" suggesting that organisational buying typically involves several individuals or groups of individuals. These can be classified into users, influencers, deciders, approvers, buyers and gatekeepers [Kotler, 1994; Kohli, 1989; Spekman and Grønhaug, 1986; Lilien and

Wong, 1984; Johnston and Bonoma, 1981; Wind, 1978; Spekman and Stern, 1979; Webster and Wind, 1972a,b].

The organisational buying process

Organisational buying is generally understood as a multi-stage process [Cardozo, 1983; Wind and Thomas, 1980]. Several models have been suggested (Figure 6.2).

Robinson & Faris (1967)	**Ozanne & Churchill (1971)**	**Webster & Wind (1972a,b)**	**Kelly (1974)**	**Bradley (1977)**	**Wind (1978)**
Problem (need) recognition	Awareness	Identify needs	Recognise need	Purchase initiation	Identification of needs
↓	↓	↓	↓	↓	↓
Determine characteristics		Establish specifications			Establish specifications
↓	↓	↓	↓	↓	↓
Describe characteristics					
↓	↓	↓	↓	↓	↓
Search sources	Interest	Identify alternatives	Information search	Survey of alternatives	Search alternatives
↓	↓	↓	↓	↓	↓
Acquire proposals					Establish contact
↓	↓	↓	↓	↓	↓
Evaluate proposals	Evaluation	Evaluate alternatives	Evaluate alternatives	Supplier short listing	Set purchase and use criteria
↓	↓	↓	↓	↓	↓
					Evaluate alternatives
↓	↓	↓	↓	↓	↓
			Approval of funds		Budget availability
↓	↓	↓	↓	↓	↓
					Evaluate alternatives
↓	↓	↓	↓	↓	↓
					Evaluate specific alternatives
↓	↓	↓	↓	↓	↓
					Negotiate
↓	↓	↓	↓	↓	↓
Select order routine	Trial	Select suppliers	Decision	Award contract	Buy
↓	↓	↓	↓	↓	↓
	Adoption				Use
↓	↓	↓	↓	↓	↓
Performance feedback					Post purchase

Figure 6.2: Illustrative formulation of the organisational buying process (adopted from Wind and Thomas, 1980)

A further model not included in the above overview of Wind and Thomas, but worth mentioning, is the *decision process model* of Robertson [1974] which includes findings of many of the previous adoption decision process models [Mahatoo, 1985]. Robertson's model is composed of eight stages: (1) Problem perception, (2) Awareness, (3) Comprehension, (4) Attitude, (5) Legitimation, (6) Trial, (7) Adoption, and (8) Dissonance.

Finally, a more recent model explaining the purchasing process of information technology worth outlining is that of Geisler and Hoang [1992]. The model comprises five decision phases: (1) Establish or articulate the need for IT, (2) Establish or determine which unit(s) will receive the new or modified IT, (3) select the technology, (4) select the supplier and, (5) authorise and sign off.

While the above models vary in complexity, they essentially describe the organisational purchase decision process by four key phases:

- Awareness or identification of needs for the purchase objects;
- Search of information about the purchase objects;
- Evaluation of the purchase objects identified including the formation of attitudes about the object and associated service;
- Adoption or rejection (after trial) of the purchase objects.

Factors influencing the organisational buying centre and process

The influences on industrial buyers investigated by some of the major past empirical studies can be grouped under four headings as illustrated in Figure 6.3[2]:

[2] A review of further past studies on factors affecting the buying decision process is available in Wind and Thomas, 1980.

Research source	Factors influencing the organisational buying centre and process
	ENVIRONMENTAL FACTORS
Moriatry and Spekman, 1984	information sources
Sheth, 1973	information sources, temporary economic conditions such as price controls, strikes and recession
Webster and Wind, 1972a,b	suppliers, customers, government, labour unions, trade associations, professional groups, other business firms, other social institutions
Ozanne and Churchill, 1971	industrial environment, information sources
Robinson and Faris, 1967	general social, cultural, economic and technical environment, general business conditions, regular business constraints, information source
	ORGANISATIONAL FACTORS
Sharma, 1994	organisational culture
Geisler and Hoang, 1992	company size
More, 1992	competitive marketing culture, integrated management teams
Barklay, 1991	barriers to communication, reward system, departmental responsibilities
Sheth, 1973	organisation orientation, organisation size, degree of centralisation
Webster and Wind, 1972a,b	organisation of the organisational buying centre and purchasing function (communication, authority, status, rewards and work flows), technology relevant for purchasing, buying task
Ozanne and Churchill, 1971	age of company, rate of growth, research & development commitment, financial constraints, number of employees, proportion of elite personnel
Robinson and Faris, 1967	communication and information, rewards, authority, status, technology level, centralised or decentralised structure
	INTERPERSONAL FACTORS
Dwyer et al, 1987	buyer-seller relationship
Michaels and al, 1987	role stress among industrial buyers
Clopton, 1984	seller and buying firm factors affecting industrial buyers' negotiation behaviour and outcome
Huppertz, Arseson and Evans, 1978	buyer-seller relationship
Webster and Wind, 1972a,b	individual buying behaviour, interactions between individuals of the organisational buying centre
Robinson and Faris, 1967	relationships between the buyers and other members of the organisation

Figure 6.3: Past research on factors influencing the organisational buying centre and process

Research source		**Factors influencing the organisational buying centre and process**
⇩		⇩
		INDIVIDUAL FACTORS
Ronchetto et al,1989	⇨	formal rank, departmental membership
Sheth, 1973	⇨	specialised education, role orientation, life style
Webster and Wind, 1972a,b	⇨	motivation, cognitive structure, personality, learning process, perceived roles
Cardozo and Cagley, 1971	⇨	job responsibility and background
Ozanne and Churchill, 1971	⇨	age, education, cosmopolitanness, mental abilities, commitment to status quo, technical orientation, professional affiliation, level in hierarchy
Robinson and Faris, 1967	⇨	individual purchase characteristics, communication habits, information handling habits, motivation, perception, individual learning processes, cognitive processes

Figure 6.3 (continued): Past research on factors influencing the organisational buying centre and process

Using the above classification of OBB research the *CVRS adoption model* of this study falls into the category concerning research on the **factors influencing the organisational buying process** as shown in Figure 6.3. The following variable classes are included (see also preceding Figure 6.1):

- Individual factors (CVRS awareness, CVRS pre-implementation attitude, school education, computer literacy etc.);

- Organisational or structural factors (centralisation of data processing function, company size, IT policy, organisational and technical maturity etc.); and

- Environmental factors (CVRS suppliers' marketing activity).

The *CVRS adoption model* is primarily validated with evidence from cross-sectional quantitative data (as opposed to longitudinal and qualitative data) provided by the survey questionnaires. As a result, there was only limited scope for paying attention to the mechanisms and the dynamics of the software's adoption process or the organisational buying centre (above first and second classification of OBB research) including the buyer-seller relationships. Similarly, there was no scope for investigating interpersonal or behavioural aspects, such as the role of conflict solving. In fact, the model considers the organisational buying process solely in terms of its outcome; that is, which factors (variables) are associated with the adoption or rejection of the software. Hence, the current *CVRS adoption model* is purely factor oriented as opposed to process oriented.

The data used for validating the model are based on the responses given by the *independent operating centres* and the associated managers with *CVRS decision-making authority* (subsequently referred to as "*CVRS decision makers*")[3].

As is typical for organisational buying processes, the CVRS adoption process is probably also influenced by organisational members other than the "*CVRS decision makers*"[4]. These are the managers without *CVRS decision-making authority* and schedulers located at the depot level. For instance, their attitude towards the software may influence the *CVRS decision makers'* attitude towards the technology and thus indirectly affect their final decision on whether or not to implement CVRS. However, the *CVRS decision makers* usually take a leading role in the CVRS approval process. Also, it is not clear to what extent the individuals without decision-making authority actually influence the software's approval. Therefore, the responses of the latter are not considered in the analysis.

6.2 Measurement of variables

All concepts, their dimensions, sub-dimensions and associated indicators of both CVRS users and CVRS non-users are measured in relation to the same point in time; that is, prior to the organisations' decision to implement the software. This is necessary in order to evaluate the effects of the independent variables (e.g. **CVRS pre-attitude, CVRS awareness**) on an organisation's decision to adopt CVRS (dependent variable). The same measurement technique applies to variables which are expected to influence the independent variables.

Therefore, organisations already using CVRS were asked to respond to the indicators retrospectively, that is in relation to the point in time prior to the installation of CVRS.

3 See Section 4.2.3 ("independent operating centre"), p. 100.

4 See above: "The buying centre", p. 141.

Hence, the indicators in the questionnaires addressed to the users of CVRS were given the addition "...initially (prior to installation)...".

Table 6.1 below illustrates this measurement technique by the example of an indicator concerning CVRS users' and CVRS non-users' pre-implementation attitude towards CVRS and level of computer experience.

Respondent	Indicator
CVRS user	"Generally speaking, how (high/low) did you **initially (prior to installation)** consider the usefulness of route planning software?" "To what extent (high/low) did you **initially (prior to installation)** use computers?"
CVRS non-user	"Generally speaking, how (high/low) do you consider the usefulness of route planning software?" "To what extent (high/low) do you use computers?"

Table 6.1: Examples of the measurement techniques used in the current research

The above technique of measurement obviously carries the risk of error, as the respondents can find it difficult to retrospectively indicate past feelings and events with great accuracy. Ideally, the analysis of independent variables influencing organisations' adoption of CVRS technology (and those variables influencing these independent variables) should be carried out as a *longitudinal* study. The potentially relevant variables would have to be measured prior to the adoption of CVRS. The companies eventually implementing CVRS would then be compared with those which failed to implement the software. Unfortunately, in practice such a survey design is extremely difficult, if not impossible, to carry out. Therefore, the technique of measurement applied in this research is considered to be the best compromise between perfect reliability and practicability. Also, good support for the validity of this procedure is given by the fact that the responses of CVRS users vary significantly from the responses of the CVRS non-users.

An exception to the above technique of measurement has been made for certain variables, for instance, the indicators of the **CVRS awareness** concept. All companies were asked to respond to this concept's indicators in relation to the time of the questionnaire administration. This was decided upon, because the initial case study research revealed that companies using CVRS were generally unable to retrospectively specify with great accuracy their awareness of CVRS prior to the software's implementation. It is assumed that the **CVRS awareness** of companies already using the software has not changed significantly between the time prior to its implementation and the time of the questionnaire administration. Support for this assumption is also given by the fact that companies planning to use CVRS in the near future are shown to have similar levels of **CVRS awareness** compared to companies already using such software.

Similarly, in companies already using CVRS, some *structural* variables, for example, **company size**, are measured by indicators relating to the point in time of the questionnaire administration. Again, it is assumed that these variables have not changed significantly between the time prior to the software's implementation and the questionnaire administration.

6.3 Variables associated with the adoption of CVRS

6.3.1 Presentation of variables

This section presents the relevant variables which are expected to be associated with the adoption of CVRS technology.

Awareness of the software available: Robinson and Faris [1967] suggests that the buyers' awareness of supply is a major determinant of their buying decisions. Evidence from the author's preliminary research suggests that companies not using CVRS are not sufficiently aware of the packages available. Also, CVRS non-users are unaware of the software's full benefits. This assumption is supported by the findings of a past empirical study which suggests: "Companies which have dismissed CRP[5] systems in the past as inappropriate were generally unaware of the progress made in CRP over the past years" [Peters and Doganis, 1987, p. 102].

CVRS pre-implementation attitude ("CVRS pre-attitude"): The purchase decision is predominantly influenced by the individuals' attitudes towards the buying objects [Robinson and Faris, 1967]. The author's initial qualitative research has revealed the widespread view that the use of CVRS technology is ineffective, unsuitable for an organisation's particular distribution environment and/or simply is too expensive.

Similar findings were made by Wright and Cross [1985, p. 12] who suggest: "The attitude of the individual, ... plays a part in the rate of innovation".

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[5] "CRP" stands for: Computerised Round Planning.

Wright and Cross [1985, p. 25] also suggest that the adoption of DSSs is influenced by the lack of importance which organisations attribute to DSSs. The authors summarise: "...predominantly companies in the freight sector are concerned with control and the minority are considering the management information systems but none were observed to be training management for decision support systems".

A further reason for the low adoption rate may be that people perceive CVRS technology as a "black-box"; that is they may find it difficult to understand the theory behind the way CVRSSs generate routes. Transaction processing systems (TPSs), such as statistical software or spreadsheet programs perform operations in exactly the same way as it is done by hand, but faster and more accurately. In contrast, CVRSSs produce routes which can be substantially different to the ones generated by the manual planner.

Industrial relations: Trade unions can strongly influence the process of CVRS approval. Their objection or, at the most extreme, massive opposition to implementing CVRS may lead to the project's dismissal. Again, Wright and Cross [1985, p. 12] suggest that "... the union influence within the industry also plays a part in the rate of innovation".

Organisation of decision-making authority: The decision to approve CVRS technology is frequently made by operating centres other than the local transport apartment where the software is implemented and used. This tends to apply to large organisations where the IT decision-making authority is often centralised. The IT decision process tends to be joint and therefore complex, involving several central departments being involved at various decision levels. The allocation of decision authority away from the final user of the software tends to delay the software's approval. At the most extreme, the software is rejected if no agreement can be reached among the various decision makers involved.

Such difficulties in the CVRS project's approval process were observed in the case study of Brewery-I. The total process was extremely complicated and lasted more than four months until the software was approved by management. Several directors were involved in the approval process - the directors of the regional and the central IT departments as well as the directors of the regional and central data processing departments. Each of the decision makers already knew either from personal experience or by word of mouth about the use of certain CVRSSs in other companies. Not surprisingly, there were varying pre-attitudes towards each CVRSS. These pre-attitudes were further influenced by other individuals in the organisation who had some knowledge or "folk memory" of

CVRS. The availability of different CVRSSs, and perhaps most importantly, the mixture in pre-attitudes and personal preferences, led to some considerable confusion. In the end, some directors preferred the *Paragon2* package while others were in favour of the *Visit* system. Overall, it proved to be difficult and extremely time consuming to reach a consensus for purchasing a single CVRS system.

The above variables form the following hypotheses:

Hypotheses 3a - 3d: The adoption of computerised vehicle routing and scheduling is associated with the potential users':
- awareness of the software available (*hypothesis 3a*);
- pre-attitude towards the software (*hypothesis 3b*);
- industrial relations (*hypothesis 3c*); and
- organisation of decision-making authority for IT in transport (*hypothesis 3d).*

6.3.2 Measurement of variables

Operationalisation of concepts

Tables 6.2 to 6.5 show the operationalisation of concepts used in *hypotheses 3a* to *3d.*

Concept	Dimension	Sub-dimension	Indicator (contents)	Indicator (label)
CVRS awareness	+Actual CVRS awareness	(not applicable)	Number of CVRSSs known	P-191
	Perceived CVRS awareness	CVRS existence	Perceived awareness of existence of CVRS	B-1
		CVRS benefits	Perceived awareness of the benefits of CVRS	B-2
		CVRS progress	Perceived awareness of development and progress made in CVRS	B-3

Table 6.2: Operationalisation of the *CVRS awareness* concept

Concept	Dimension	Sub-dimension	Indicator (contents)	Indicator (label)
CVRS pre-attitude	+ General VRS pre-attitude	(not applicable)	General usefulness of CVRS	C-5
			General importance of CVRS for company's physical distribution	C-7
			Benefits provided by CVRS	C-9

Table 6.3: Operationalisation of the *CVRS pre-attitude* concept

CV RS pre-atti-tude	Quality of CVRSS relative to dis-tribution environ-ment	+ Transport	Capability of CVRS to deal with delivery constraints	C-34
		+ Warehouse A	Financial justification for installing CVRS at all depots	C-35
		Warehouse B	Organisational justification for installing CVRS at all depots	C-36
		Warehouse C	Capability to achieve cost savings in customer allocations	C-37
		Warehouse D	CVRSS's impact on order picking and assembly	C-38i
		+ Service A	Customers' willingness to accept change in service	C-39
		+ Service B	Impact of change in service on customers' good will	C-40i
		Service C	Customers' view of CVRSS's impact on service level	C-41
		Service D	Ability of CVRSS to deal with late customer orders	C-42
		Customer base	Required time and resources of data collection/handling	C-43
		+ Delivery area	Quality of CVRSS's road network	C-44
		Demand	Impact of seasonal fluctuations in demand on vehicle size	C-45i
	Compa-tibility	(not appli-cable)	Compatibility of CVRS with other soft- and hardware	C-81
	+ Cost effaceency of CVRSS	(not appli-cable)	Balance between costs and expected benefits of CVRS	C-74
	Purchase power	(not appli-cable)	CVRSS's costs relative to budget available	C-75

Table 6.3 (continued): Operationalisation of the *CVRS pre-attitude* concept

Con-cept	Dimen-sion	Sub-dimension	Indicator (contents)	Indicator (label)
In-dus-trial rela-tions	Drivers' Union	General union policy	Union's policy towards management decisions affecting the staff's work	D-12
		+ Union's project support	Union's reaction towards planned implementation of CVRS	D-13
		+ Non-work based union representative's project support	Non-work-based union representative's reaction towards planned implementation of CVRS	D-14
		+ Shop steward's support	Work-based union representative's reaction towards planned implementation of CVRS	D-15
	Staff's Union	General union policy	Union's policy towards management decisions affecting the staff's work	D-17
		+ Union's support	Union's reaction towards planned implementation of CVRS	D-18
		+ Non-work based union representative's support	Non-work-based union representative's reaction towards planned implementation of CVRS	D-19
		+ Shop steward's support	Work-based union representative's reaction towards planned implementation of CVRS	D-20

Table 6.4: Operationalisation of the *industrial relations* concept

Concept	Dimension	Indicator (contents)	Indicator (label)
Organisation of decision-making authority	Centralisation	Centralisation of decision-making authority concerning corporate investment or organisational changes in transport	E-22
		Transport department's decision-making authority regarding the purchase of IT	E-23i
	Involvement	DP department's involvement in decisions concerning purchase of IT in transport	E-24

Table 6.5: Operationalisation of the *organisation of decision-making authority* concept

Among the dimensions or sub-dimensions of the **CVRS pre-attitude** and **industrial relations** concept some are assumed to be more important or better measures of the overall concepts measured than others. The dominant dimensions and sub-dimensions are labelled with a plus ("+").[6]

Selection of scales and formation of indices

The **actual CVRS awareness**[7] dimension has been measured by an index based on a list of names of 20 CVRS packages. The list is considered comprehensive including names of all current and past systems available on the British market. The index is explained in Table 6.6.

Response category for each CVRSS listed	Score per response category	Max. score
1. Respondent has only heard about the availability of the software but has no further knowledge of its features and price	1	20
2. Respondent is aware of the software's features	2	40
3. Respondent is aware of the software's purchase price.	1	20
A respondent's awareness is specified by the sum of scores obtained for each of the 20 CVRSSs listed in the questionnaire. Note that a respondent cannot tick all three categories at the same time, but either one of the three or categories 2 and 3. Hence, a respondent knowing about the features and purchase price of all 20 CVRSSs listed in the questionnaire would obtain a maximum score of 60 (20 x 2 + 20 x 1). The maximum score of 60 is rather a theoretical value, as the list in the questionnaire also includes CVRSSs which are no longer available on the market.		

Table 6.6: *Actual CVRS awareness* index

6 See Section 1.4.2.1, p. 29.

7 See Table 6.2, p. 150.

All remaining independent variables operationalised in Tables 6.2 to 6.5 have been measured on a *semantic differential seven-point scale.*

The indicators C-5, C-7 and C-9 of the **general CVRS pre-attitude** dimension (see above Table 6.3) relate to both the managers and schedulers. An identical set of indicators (C-6d; C-8d, C-10d[8]) relates to the drivers. Since all indicators correlate highly at the 1% significance level within each group of individuals, the indicators were averaged to form a **CVRS pre-attitude index** for managers (indicator: C-10xm), schedulers (indicator: C-10xs) and drivers (indicator: C-10y). Similarly, the indicators E-22 and E-23i (see Table 6.5 above) relating to the **centralisation** dimension of the **organisation of decision-making authority** concept were combined to form a **centralisation of decision-making index** (indicator: E-23x).

Reliability and validity of measurement

The above **CVRS pre-attitude indices** of managers, schedulers and drivers are considered reliable and valid measures as substantiated below:

R*eliability* or *internal consistency* of the index-measures is emphasised by high *Cronbach Alpha coefficients* which, with only one exception, are well above the minimum level of 0.8 (Table 6.7).

CVRS pre-attitude index	Cronbach Alpha Coefficient
Managers' CVRS pre-attitude index	0.93
Schedulers' CVRS pre-attitude index	0.92
Drivers' CVRS pre-attitude index	0.93
Centralisation of decision-making index	0.80

Table 6.7: Cronbach Alpha coefficient for testing the reliability of *individuals' (managers, schedulers, drivers) CVRS pre-attitude* indices

Construct validity of the index-measures is emphasised by *factor analysis* which facilitates the extraction of a single factor for each index. The indicators load substantially higher than the minimum score of 0.6[9]. Further support is given by the overall high correlation (*total score correlation*) between individual indicators and the sum of the other indicators (Tables 6.8 - 6.11).

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8 See Appendix 1 , p. A-1f.

9 Only indicators with factor loading of ≥ 0.6 should be considered in the factor interpretation; See Section 5.2.2 ("Factor analysis"), pp. 135-136.

Indicator (Contents)	Factor loading	Total score correlation	p %
+ General usefulness of CVRS	0.95	0.81	1
+ General importance of CVRS for company's physical distribution	0.94	0.79	1
+ Benefits provided by CVRS	0.96	0.83	1

Table 6.8: Factor analysis and total score correlation for testing construct validity of *managers' CVRS pre-attitude* index

Indicator (Contents)	Factor loading	Total score correlation	p %
+ General usefulness of CVRS	0.93	0.79	1
+ General importance of CVRS for company's physical distribution	0.91	0.77	1
+ Benefits provided by CVRS	0.92	0.79	1

Table 6.9: Factor analysis and total score correlation for testing construct validity of *schedulers' CVRS pre-attitude* index

Indicator (Contents)	Factor loading	Total score correlation	p %
+ General usefulness of CVRS	0.92	0.84	1
+ General importance of CVRS for company's physical distribution	0.96	0.89	1
+ Benefits provided by CVRS	0.95	0.87	1

Table 6.10: Factor analysis and total score correlation for testing construct validity of *drivers' CVRS pre-attitude* index

Indicator (Contents)	Factor loading	Total score correlation	p %
Centralisation of decision-making authority concerning corporate investment or organisational changes in transport	0.91	0.62	1
Transport department's decision-making authority regarding the purchase of IT	0.91	0.62	1

Table 6.11: Factor analysis and total score correlation for testing construct validity of *centralisation of decision-making* index

Data analysis

The relationships between the independent or influencing variables of *hypotheses 3a* to *3e* are evaluated individually by the *Kruskal-Wallis test*. Two dependent or response classification variables are used each of which is based on a nominal scale. The first classification variable groups the respondents into:

- Organisations using CVRS ("*Current CVRS users*") and
- Organisations not using CVRS ("*Current CVRS non-users*").

The second classification variable has the categories:

- Organisations using CVRS and organisations planning to use CVRS in the near future ("*current + future CVRS users*") and
- Organisations not using CVRS and not planning to use CVRS in the near future ("*current + future CVRS non-users*").

The second classification variable is considered the more meaningful, as the research aims to investigate the effect of variables on an organisation's decision to implement CVRS. In this respect, organisations planning to use CVRS are expected to have the same or similar characteristics as those organisations already using CVRS. Therefore, the statistical results will be presented with focus on this second classification variable. The data analysis ignores respondents who were unable to specify whether or not they would be using CVRS in the near future.

It should be recognised that data pertaining to the **industrial relations** concept (Table 6.4) has not directly been collected from the trade unions. Instead, these data have been provided by the managers with CVRS decision-making authority. This procedure is considered to be valid, because the research aims to investigate the impact of **industrial relations** on the managers' decision to adopt CVRS technology. Therefore, **industrial relations** are best measured in terms of the decision makers' perceptions (**perceived industrial relations**).

6.3.3 Results

Tables 6.12 and 6.13 show the results of the *Kruskal-Wallis test* performed on *hypotheses 3a* to *3b* and hypotheses *3c* to *3d* respectively.

Independent variable		Dependent variable					
A	B	C			D		
Dimension	Sub-dimension	Current user/non-users of CVRS			Current + future users/non users of CVRS		
		CVRS use Rank	CVRS non use Rank	p %	CVRS use Rank	CVRS non use Rank	p %
CVRS AWARENESS							
Perceived CVRS awareness	CVRS existence	26.0	19.2	**10**	23.2	15.5	**5**
	CVRS benefits	27.8	18.5	**5**	23.5	15.2	**1**
	CVRS progress	25.7	19.3	**10**	22.4	16.1	**5**
+ Actual awareness	(not applicable)	33.6	15.5	**1**	27.3	12.0	**1**
CVRS PRE-ATTITUDE							
+ General CVRS pre-attitude	(not applicable)	25.5	19.4	ns	24.7	14.2	**1**
Pre-attitude to CVRS relative to organisations distribution environment	+ Transport	26.3	19.1	**10**	25.4	13.5	**1**
	+ Warehousing A	14.9	9.6	**10**	14.0	5.3	**1**
	Warehousing B	13.7	10.3	ns	12.5	7.4	**5**
	Warehousing C	21.9	15.7	**10**	18.8	14.7	ns
	Warehousing D	27.7	18.6	**5**	22.6	16.0	**10**
	+ Service A	22.9	18.9	ns	23.0	14.2	**1**
	+ Service B	29.7	17.0	**1**	22.5	15.3	**5**
	Service C	22.1	16.6	ns	19.6	13.4	**10**
	Service D	16.8	19.9	ns	17.3	17.7	ns
	Customer base	22.0	17.0	ns	16.4	16.6	ns
	+ Delivery area	26.2	16.4	**1**	23.5	12.2	**1**
	Demand	25.0	18.0	**10**	20.2	17.8	ns
CVRS compatibility	(not applicable)	13.8	18.7	ns	12.9	18.0	ns
+ CVRS cost efficiency	(not applicable)	21.3	18.6	ns	21.0	14.3	**5**
Purchase power	(not applicable)	17.6	18.2	ns	16.5	16.5	ns

Table 6.12: Kruskal-Wallis test of *hypotheses 3a* and *3b* (p. 150)

Independent variable		Dependent variable					
A	B	C			D		
Dimension	Sub-dimension	Current user/non-users of CVRS			Current + future users/non users of CVRS		
		CVRS Use Rank	CVRS non use Rank	p %	CVRS use Rank	CVRS non use Rank	p %
	INDUSTRIAL RELATIONS						
Drivers' Union	General union policy	11.8	20.5	**5**	14.6	17.3	ns
	+ Union's project support	13.3	19.3	**10**	14.5	16.4	ns
	+ Non-work-based union representative's support	6.3	10.4	ns	7.6	9.8	ns
	+ Shop steward's support	13.3	18.0	ns	15.1	15.9	ns
Staff's union	General union policy	12.8	10.3	ns	11.8	8.6	ns
	+ Union's support	12.7	9.4	ns	11.1	8.5	ns
	+ Non-work-based union representative's support	7.5	5.0	ns	5.8	5.3	ns
	+ Shop steward's support	8.1	8.7	ns	8.5	9.5	ns
DECISION-	MAKING AUTHORITY						
Centralisation	(not applicable)	20.5	20.5	ns	19.91	18.23	ns
Involvement	(not applicable)	15.36	17.81	ns	14.91	16.18	ns

Table 6.13: Kruskal-Wallis test of *hypotheses 3c* and *3d* (p. 150)

The results for each dimension and sub-dimension analysed are discussed below:

CVRS awareness: Significant differences in the various **CVRS awareness** dimensions or sub-dimensions are found in relation to both classification variables. The most significant results are found in relation to the second classification variable (Table 6.12: column D).

Current CVRS users have significantly higher rankings than current CVRS non-users (Table 6.12: column C). Equally, current plus future CVRS users have higher rankings than current plus future CVRS non-users (Table 6.12: column D). The dimension **actual CVRS awareness** (indicator: P-191) is weighted "+", as it is considered to be the best measure of an organisation's actual awareness of CVRS technology available. The dimension shows a highly significant difference in relation to both classification variables.

The average responses given to each of the **CVRS awareness** dimensions or sub-dimensions by the groups *current and future CVRS user* and *current and future CVRS* *non-users* are shown in the following Table 6.14[10]. As suggested by the above findings of the *Kruskal-Wallis test*, the *current and future CVRS users* (column C) have a significantly higher average CVRS awareness than the *current and future CVRS non-users* (column D). The highest difference is observed with regard to the **actual CVRS awareness** dimension.

A	B	C	D	E
Dimension	**Sub-dimension**	**Current + future CVRS users**	**Current + future CVRS non-users**	**Max. score obtainable**
		Mean score	**Mean score**	
+ Actual CVRS awareness	(not applicable)	13.6	2.55	60
Perceived CVRS awareness	CVRS existence	5.8	4.5	7
	CVRS benefits	5.8	4.5	7
	CVRS progress	5.4	4.3	7

Table 6.14: Average scores of *CVRS awareness* dimensions/sub-dimensions

Further analysis of individual responses given with respect to the **actual CVRS awareness** dimension by the 20 "current and future CVRS non-users" reveals the following picture:

- 7 or 35% of the respondents were not aware of the existence, features or price of any of the 20 CVRSSs listed in the questionnaires;
- 4 or 20% of the respondents had only heard about one system;
- 1or 5% of the respondents had only heard about two systems; and
- 3 or 15% of the respondents had only heard about three systems.

CVRS pre-attitude: Overall, current users of CVRS rank higher than current CVRS non-users. Half of the tested relationships are significant at the 1%, 5% or 10% level (Table 6.12: column C). Similar findings are obtained for the respondents categorised by the second classification factor. However, the great majority of tested relationships are significant, with more than half at the 1% and 5% level (Table 6.12: column D).

Nearly all dimensions or sub-dimensions labelled "+" show significant or highly significant differences in relation to the second classification variable (Table 6.12: column D).

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10 For further detail see Table A2-3 (Appendix 2), p. A-29.

The findings which are significant at the 1% to 5% level are outlined below in further detail:

Current and future users of CVRS

- consider the general benefits, usefulness and importance of CVRS technology higher than current and future CVRS non-users do (indicator: C-10x).
- perceive CVRS technology to be significantly more capable of coping with delivery constraints than current and future non-users do (indicator: C-34).
- perceive the implementation of CVRS technology at all of their depots to be both financially and organisationally more justifiable than the contrast group (indicator: C-35, C-36).
- felt more positively about their customers' willingness to accept a change in the service level caused by the implementation of CVRS (indicator: C-39). Equally, this group of respondents was less concerned about a potential loss in goodwill resulting from such a change in the service level (indicator: C-40i).
- estimate the accuracy of the computer generated routes compared to actual routes to be significantly higher than the contrast group does (indicator: C-44).
- judge the balance between the technology's costs and benefits to be more favourable than current and future CVRS non-users do (indicator: C-74).

The responses to each of the pre-attitude dimensions for the groups *current and future CVRS users* and *current and future CVRS non-users* are summarised in Table 6.15[11]. Again, the data reflect the findings of the *Kruskal-Wallis test* performed. The highest variations in scores are found with regard to the indicators relating to the **general CVRS pre-attitude** dimension and the dimensions or sub-dimensions marked with a "+".

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[11] For further detail see Table A2-4 (Appendix 2), p. A-30.

A	B	D	D	E
Dimension	Sub-dimension	Current + future CVRS users Mean score	Current + future CVRS non-users Mean score	Max. score obtainable
+ General CVRS - pre-attitude	(not applicable)	6.2	4.7	7
Pre-attitude to quality of CVRSS relative to distribution environment	+ Transport	5.6	3.8	7
	+ Warehouse A	5.1	1.8	7
	Warehouse B	5.7	4.4	7
	Warehouse C	5.0	4.4	7
	Warehouse D	4.3	3.0	7
	+ Service A	4.2	2.9	7
	+ Service B	3.6	2.4	7
	Service C	3.8	2.8	7
	Service D	3.8	3.9	7
	Customer base	3.8	3.8	7
	+ Delivery area	6.1	4.6	7
	Demand	4.2	3.7	7
Compatibility	(not applicable)	5.4	6.1	7
+ Costs efficiency	(not applicable)	5.7	4.7	7
Purchase power	(not applicable)	4.8	4.8	7

Table 6.15: Mean scores of *CVRS pre-attitude* dimensions/sub-dimensions

Industrial relations and **organisation of decision authority:** Almost none of the dimensions' indicators or indices are found to be significantly different between the "*current CVRS users*" and "*current CVRS non-users*" (first classification variable; Table 6.13: column C). The same applies to the "*current and future CVRS users*" as well as the "*current and future CVRS non-users*" (second classification variable; Table 6.13: column D). Hence, the dimensions appear to have no significant influence on an organisation's decision to implement CVRS technology.

However, two dimensions are worth pointing out. The drivers' **general union policy** and **union's project support** dimensions show significant and moderately significant differences between the groups of the first classification variable (Table 6.13: column C). Contrary to *hypothesis 3c*, the current CVRS non-users indicated more positive ratings than the current CVRS users. This situation may be an indication that the union's general policy towards management decisions affecting the staff's work and their support of IT such as CVRS has improved over recent years. Whilst in the past the users of CVRS had to cope with opposition from the drivers' unions, today's potential users may be less concerned about this issue.

This view is supported by Brewery-B which has been using CVRS for more than 10 years. Management reported that the unions have become more receptive to IT. This has significantly facilitated the implementation of computer systems within the company.

6.3.4 Summary

The research provides evidence that an organisation's decision to implement CVRS technology is associated with variables of the **CVRS awareness** concept and **CVRS pre-attitude** concept. Thus, the data confirm *hypothesis 3a* and *hypothesis 3b*. The variables found significant at the 1% and 5% levels are summarised in Table 6.16.

Concept	Dimension	Sub-dimension	Indicator (contents)
CVRS awareness	Perceived CVRS awareness	Existence	Perceived awareness of existence of CVRS
		Benefits	Perceived awareness of the benefit
		Progress	Perceived CVRS development and progress of CVRS
	+ Actual CVRS awareness	(not applicable)	Number of CVRSSs known
CVRS pre-attitude	+ General CVRS pre-attitude	(not applicable)	Usefulness of CVRS Importance of CVRS for company's physical distribution Benefits provided by CVRS
	CVRS relative to organisations' distribution environment	+ Transport	Capability of CVRS of dealing with delivery constraints
		Warehouse A	Financial justification for installing CVRS at all depots
		Warehouse B	Organisational justification for installing CVRS at all depots
		+ Service A	Customers willingness to accept change in service
		+ Service B	Impact of change in service on customers' goodwill
		Customer base	Time and resources needed for data collection and handling
		+ Delivery area	Quality of CVRSS's road network
	+ Costs efficiency of CVRSS	(not applicable)	Balance between costs and expected benefits of CVRS

Table 6.16: Variables significantly ($p \leq 5\%$) associated with the *adoption of CVRS technology*

Regarding causality, there is good reason to predict *a priori* that **CVRS pre-attitude** and **CVRS awareness** precede and, therefore, influence the adoption of CVRS.

6.4 Variables associated with the awareness of CVRS

6.4.1 Presentation of variables

The variable **CVRS awareness** (indicators: B-1, B-2, B-3, P-191) was shown to be associated with the adoption of CVRS technology. This section extends the scope of the investigation by analysing the variable **CVRS awareness** with respect to certain independent variables.

Company size: Wright's [1988] study on the use of distribution software suggests that small and medium sized companies often lack both the inclination and resources to explore technological innovations. This situation is likely to apply also to the use of CVRSSs which are a rather specialised and comparatively expensive type of software. The software is developed and distributed by a few, mainly small and specialised, software houses. Moreover, large companies are more likely to be directly approached by the software suppliers by direct marketing via personal visits or telephone calls from sales agents and targeted mail shots.

Centralisation of the data processing function: Companies organise their data processing or information system functions in two general forms. In its most centralised form, the function is carried out by an autonomous data processing department or an equivalent service department, for example a business system department or logistics system department. Each individual has clearly defined responsibilities. In its most decentralised form, in contrast, the function is carried out by a formal or informal project team. The team usually consists of a number of employees from different departments who have some sort of special data processing knowledge. The responsibilities and tasks of each of the team's members are much less clear-cut [Ein-Dor and Segev, 1981].

It is assumed that organisations with an autonomous data processing department or other equivalent departments are more likely to have the aforementioned inclination and financial as well as personnel resources to explore and thus be aware of the CVRSSs available

Software suppliers' marketing activity: CVRS technology is usually distributed by the software's producers themselves. Two out of eight suppliers have appointed external distribution software houses as their authorised dealers. Six out of eight suppliers have specialised in CVRS technology as the only type of software. Hence, CVRS technology is sold by a few mainly small companies with, consequently, limited marketing resources.

In fact, some suppliers have less than five full time personnel. Interviews with potential and current users of CVRS packages suggest that only a few organisations have learned about the availability of CVRS technology from direct marketing by the software's suppliers. This gives reason to hypothesise that the marketing activity of CVRS suppliers is insufficient and has failed to inform potential users about the availability of their CVRSSs.

The above factors form the following hypotheses:

Hypotheses 4a - 4b: The awareness of CVRS technology is positively associated with the potential users':

- company size (*hypothesis 4a*); and
- centralisation of the data processing or equivalent service function (*hypothesis 4b*).

Hypothesis 5: The software suppliers' marketing activity has not led to a significant awareness of CVRSSs available.

6.4.2 Measurement of variables

Operationalisation of concepts

Tables 6.17 to 6.19 show the operationalisation of the concepts used in *hypotheses 4a*, *4b* and *5*. The operationalisation of the **CVRS awareness** concept (indicator: B-1, B-2, B-3, P-191) has been presented previously in Table 6.2[12] .

Concept	Dimension	Indicator (contents)	Indicator (label)
Company size	Sales revenue	Turnover in £ p. a.	Q-190a
	Delivery volume	Tonnes delivered p. a.	Q-190b
	Customers	Number of daily customers to be delivered	Q-190c
	Vehicle fleet	Number of HGVs available	Q-190d

Table 6.17: Operationalisation of the *company size* concept

12 See Table 6.2, p. 150.

Concept	Dimension	Indicator (contents)	Indicator (label)
Centralisation of data processing or equivalent service function	(not applicable)	Number of autonomous technical service departments involved in issues of data processing	R-191

Table 6.18: Operationalisation of the *centralisation of data processing or equivalent service function* concept

Concept	Dimension	Indicator (contents)	Indicator (label)
Suppliers' communica-tion policy	Suppliers' marketing activity	Number of advertisements, case studies, conferences etc. p.a.	S-42
	Companies' information source about CVRS	Ranking of sources from which companies received most information about CVRS	S-192

Table 6.19: Operationalisation of the *software suppliers' marketing activity* concept

Selection of scales and formation of indices

The **company size** concept is measured by an *overall* index composed of four dimensions. The dimensions' indicators, which originally were based on a ratio scale, have been transformed on to an ordinal scale which is based on four categories (Table 6.20). A respondent's total size is determined by averaging the scores obtained for each indicator. For instance, a respondent with

- annual sales of more than £200 million (category 4),
- delivery volume of more than 200,000 tonnes(category 4),
- 320 daily customers (category 4), and
- 45 vehicles (category 3)

is specified as a large company (mean score: 3.75). Scores of 0.25 and 0.75 are rounded down and up respectively.

Score	Company size category	Dimension			
		Sales revenue (million £)	Delivery volume (1,000 tonnes)	Daily customers	Vehicles
1	small	1 - 40	1 - 40	0 - 100	0-15
2	small-medium	41 - 100	41 - 100	101 - 200	16 - 30
3	medium-large	101 - 200	101 - 200	201 - 300	31 - 50
4	large	> 200	> 200	> 300	>50

Table 6.20: *Company size* index

The concept **centralisation of data processing or equivalent service function** (below referred to as "**data centralisation**") is measured by an indicator (R-191) based on an ordinal scale. Each autonomous technical service department involved in issues of data processing in a respondent's company accounts for a score of one. The sum of scores represents the measure for the degree of centralisation. The higher the scores, the higher the centralisation.

The dimension **companies' information source about CVRS** is measured by an indicator (S-192) based on a nominal scale. The respondents were asked to rank a list of six sources thus indicating the contribution of each source to their awareness of CVRS. The highest rank of 6 is attributed to the source which supplied most information, the rank 5 was given to the source which contributed second most to their knowledge of CVRS etc.

The dimension **suppliers' marketing activity** is measured by an indicator (S-42) based on an ordinal scale or a nominal scale as appropriate. By the use of a questionnaire the software suppliers indicated which media were used to inform the public about the availability of their software. If possible, the suppliers also indicated the extent to which the media were used, for example the number of annual publications in trade journals.

Reliability and validity of measurement

Reliability and validity testing is not performed for the company size index, as it is composed of different dimensions. These do not necessarily correlate with one another or have the same underlying structure. For instance, two breweries may have the same annual delivery volume in tonnes, but have different numbers of daily orders, as these may vary considerably in tonnes per order. Also, the two breweries may have different fleet sizes, depending on the actual requirements. One brewery with large numbers of customers in city centres may have many small vehicles. The other brewery may operate predominantly in rural areas and therefore runs fewer but larger vehicles.

Data analysis

Hypotheses 4a and *4b* are evaluated by the *Spearman's rank correlation test. Hypothesis 5* is tested by univariate statistics.

6.4.3 Results

Table 6.21 shows the results regarding the *Spearman's rank correlation test* performed with variables of *hypotheses 4a* and *4b*[13].

Dependent variable Dimension	Independent variable Concept	RCC	p (%)
+ Actual CVRS awareness	Company size	0.50	**1**
+ Actual CVRS awareness	Data centralisation	0.38	**1**
CVRS existence (perceived awareness)	Company size	0.09	ns
CVRS benefits (perceived awareness)	Company size	0.12	ns
CVRS progress (perceived awareness)	Company size	0.23	ns
CVRS existence (perceived awareness)	Data centralisation	0.35	**5**
CVRS benefits (perceived awareness)	Data centralisation	0.34	**5**
CVRS progress (perceived awareness)	Data centralisation	0.37	**5**

Table 6.21: Spearman's rank correlation test for *hypotheses 4a* and *4b*

The key dimension **actual CVRS awareness**, which is weighted "+", has a highly significant positive association with both **company size** and **data centralisation**. The relationships between dimensions of **perceived CVRS awareness** and **data centralisation** are also consistently significant at the 5% level.

The following Table 6.22 summarises the responses given to the sub-dimension **companies CVRS information source** used in *hypothesis 5*.

[13] For further detail see Table A2-6 (Appendix 2), p. A-31.

A Information Source	B 1	2	3	4	5	6	C Sum of ranks	D Rank frequency	E Average ranks
Reputation	0	0	0	2	2	15	108	19	5.7
Exhibition	0	0	1	1	3	3	45	8	4.4
Conference/Seminar	1	1	0	3	2	1	31	8	3.9
Advertisement	0	1	2	2	1	2	33	8	4.1
Mailing lists	0	0	3	0	2	1	25	6	4.1
Personal selling	0	1	0	0	0	2	14	3	4.7

Column B

Column B indicates the respondents' ranking of information sources, shown in column A, from which they have learned about CVRS. The information sources which the respondents ranked highest are given a score of 6, the source which is ranked second highest a score of 5 etc. The table ignores those respondents who indicated that they had learned about CVRS from more than one source, but failed to indicate a rank order.

Column C

The calculation of the sum of ranks is demonstrated by the example of the information source *reputation* which scores 108. The sources have been indicated

- 15 times as the most important source of information (hence was given 15 times the highest rank 6 which equals the sum of 90),
- twice as the second most important source (i.e. twice the second highest rank 5 = 10) and
- twice as the third most important source (i.e. twice the rank 4 = 8).

In contrast, *personal selling* has been mentioned only twice as the most important source of information (2 x 6 = 12) and once as the fifth important source (1 x 2). Hence, its total sum of ranks amounts to 14.

Column E

The average ranks are the quotient of the ranks in *column C* and the frequency a source has been mentioned (Column D). Hence, *reputation* with an average rank of 5.7 is the quotient of 108 and 19.

Table 6.22: Summary statistics (a) for *hypothesis 5*

To summarise, *reputation* or *word of mouth* clearly appears to be the most important information source from which companies learn about the availability of CVRS. In contrast, the other information sources, over which CVRS suppliers have direct control, appear to have contributed comparatively little to organisations' awareness of CVRS technology. These findings are supported by evidence shown in Table 6.23.

A	B	C
Information Source	**Number of respondents having learned about CVRS from one source only**	**Number of respondents not having learned about CVRS from any sources at all**
Reputation	11 (26%)	13 (31%)
Exhibition	0	
Conference/Seminar	0	
Advertisement	0	
Mailing lists	1 (2%)	
Personal selling	1 (2%)	
Other	0	

Table 6.23: Summary statistics (b) for *hypothesis 5*

Nearly one third or 13 out of 42 respondents have not learned about the availability of CVRS from any of the sources of information listed (Table 6.23: column C). More than one quarter or 11 out of 42 respondents have learned about CVRS via reputation only (Table 6.23: column B. In contrast, only 2% or one respondent has learned about CVRS exclusively from *personal selling* and one has learned from *mailing lists.*

Table 6.24 shows the responses to the **CVRS suppliers marketing activity** dimension. The data were collected from interviews and questionnaires completed by the CVRS suppliers. The data cover the suppliers' marketing activities undertaken from 1988 to 1993.

Name of CVRSS	Advertisements (Number)	Case Studies (Number)	Exhibitions (Number)	Conference (Number)	Direct mail
System-A	**1 p.a.**	1 p.a.	3 p.a.	1 p.a.	yes
System-B	**1 p.a.**	yes	**no**	**no**	yes
System-C	about 6 p.a.	8 until today	1 p.a.	**no**	yes
System-D	4-13 p.a.	**no**	2-4 p.a.	**no**	yes
System-E	**no**	1-3 p.a.	1 p.a.	**no**	yes
System-F	**no**	occasionally	**no**	**no**	yes
System-G	**no**	yes	1-2 p.a.	1 p.a.	yes
System-H	yes	yes	yes	**no**	yes
System-I	**no**	**no**	**no**	**no**	yes

Table 6.24: Marketing activity of CVRS suppliers 1988 - 1993

The findings reveal an overall low level of marketing activity undertaken by the suppliers of CVRS technology over the past six years. Four out of nine suppliers did not advertise at all in journals or other publications. Also, three suppliers did not present their products at any exhibitions.

But even among those suppliers who had some sort of marketing activity, this tended to be rather limited. This is hardly surprising in view of the extremely small size of most suppliers, who have limited financial and human resources to market their products. In fact, most suppliers felt that, overall, their marketing policy was insufficient to fully inform potential users about the "practical" benefits of their products. At the same time, the suppliers emphasised the importance of marketing, particularly since the number of competitive suppliers has significantly increased over recent years. Most suppliers indicated plans to give a substantially higher priority to the marketing of their software.

The majority of suppliers rely on the cheapest form of marketing - direct mailing. Exhibitions were reported to be the generally most effective, but also the most expensive marketing channel. Exhibitions give the potential users the opportunity to discuss their specific transport problems with expert sales personnel and thus get a "first feeling" for the suitability of CVRS for their particular requirements. Also, and, perhaps most importantly, exhibitions are believed to increase general awareness of individual CVRSSs. This is because people tend to more easily recall products seen at exhibitions. Subsequently, the information is passed on by word of mouth.

Strong marketing emphasis was also given to the publication of case studies on the applied use of CVRS technology. However, despite the estimated high marketing effect of case studies, the CVRS suppliers were generally unable to supply these in sufficient numbers. The most credible and, in marketing terms, most effective form of case studies were believed to be those written by external or independent authors. But again, the publication of such case studies tends to be rare.

A good marketing effect is also expected from the publication of so called "features" in specialised trade journals which inform their readership about the latest developments of certain CVRSSs.

Most suppliers allocated a rather low priority to advertisements in journals and other publications, as they believed these failed to illustrate the practical aspect of the software. The highest level of advertising was observed among those suppliers relatively new on the market. More established suppliers generally felt that the public was sufficiently aware of the availability of their products. Their marketing effort focuses on convincing potential users about the benefits of their packages, in particular by comparison with competitive products.

6.4.4 Summary

The results suggest significant to highly significant positive associations between an organisation's actual as well as perceived awareness of CVRS and the degree of centralisation of its data processing or equivalent function. Thus, the data confirm *hypothesis 4b.*

Mixed results are found with respect to a company's awareness of CVRS and the size of the organisation. Here highly significant results are only available for the relationship between an organisation's size and its actual awareness of CVRS. The latter dimension is labelled "+", as it is a more meaningful measure of a firm's overall awareness of CVRS than perceived CVRS awareness. Therefore, the results are considered to provide sufficient evidence to also support *hypothesis 4a* stating that an organisation's awareness of CVRS is positively associated with its size.

The data also suggest that organisations receive most information about CVRS via channels other than those used by CVRS suppliers. A significant number of organisations have not received any information at all from the suppliers' marketing activity. Organisations learn most about CVRS by word of mouth. Hence, the survey of the current and potential users or the *demand side* of CVRS suggests an apparent lack of marketing effort undertaken by the suppliers of the software. Similar evidence was found from the survey of the *supply side* of CVRS; that is, the apparent marketing deficit has been confirmed by most suppliers.

Most of the potential CVRS users (current and future CVRS non-users) have a very limited knowledge of CVRSSs available on the market. It is interesting to note that this stands in sharp contrast to the belief held by most of the software's established suppliers. Hence, the evidence supplied confirms *hypothesis 5.*

6.5 Variables associated with the pre-attitude towards CVRS

6.5.1 Introduction

In the previous section 6.3 the **CVRS pre-attitude** concept was shown to be positively associated with the adoption of CVRS technology. This section extends the scope of the investigation by analysing the **CVRS pre-attitude** with respect to independent variables acting on it. For this purpose, the operationalisation of the **CVRS pre-attitude** concept needs to be reconsidered as follows:

Operationalisation of concepts

The **CVRS pre-attitude** concept has been previously operationalised in Table 6.3[14]. It includes various dimensions covering individuals' *general* as well as various *specific* aspects of pre-attitude towards the software or towards changes expected to be induced by the software.

This section aims to analyse the impact of variables operationalised in general terms (e.g. general school education, general computer literacy etc.) on **CVRS pre-attitude**. Therefore, **CVRS pre-attitude** will also be operationalised in general terms using the *managers' CVRS pre-attitude index* as shown previously[15].

Results

The analysis of associations between independent variables and **CVRS pre-attitude** within the *CVRS adoption model* exclusively concerns the managers who decide on the adoption of CVRS technology by their organisations ("*CVRS decision makers*"). The aim of the analysis is to identify which variables ultimately allow for explaining or predicting the adoption of CVRS technology. Overall, the data based on responses of these *CVRS decision makers* confirm at least that the associations between **CVRS pre-attitude** and the independent variables investigated are generally positive or negative as expected. However, only a few associations are found to be significant.

This situation gives ground for supposing that the associations are weak overall and the number of responses of the *CVRS decision makers* may be too small to substantiate the existence of the associations expected. Some support for this assumption is provided by the fact that some of the associations turned out to be significant when tested with a substantially larger data set of up to 143 responses per association between two variables analysed. This data set has been obtained by adding to the *CVRS decision makers* other participants in the survey including managers without *CVRS decision-making authority* and schedulers. Tested with this enlarged data set using the *Spearman's rank correlation test*, **CVRS pre-attitude** of managers and schedulers has significant and positive

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[14] See Table 6.3, p. 150.

[15] See Section 6.3.2, pp. 150-154.

association with several variables (concepts or dimensions of concepts) as presented in Table 6.25:

Indicator (contents)	Indicator (label)	RCC	Sign. level (p in %)
Extent to which the respondents' overall company policy emphasises the importance of investment in IT in general	F-27	0.20	1
Extent to which the respondents' overall company policy emphasises the importance of investment in IT in transport	F-28	0.25	5
Extent to which the respondents' overall company policy gives higher priority to IT in transport compared with other functions	F-29	0.30	5
Companies'/distribution sites' organisational maturity in terms of the extent to which distribution data used in CVRS is readily available	F-31	0.21	10
Companies'/distribution sites' organisational maturity in terms of the extent to which responsibilities of staff and management are documented in detailed job descriptions	F-32	0.33	1
Extent of individuals' computer usage	M-57	0.24	1
Extent of educational (college/in-house) computer training	M-58	0.25	1
Estimate of the importance of transport cost information	F-62	0.20	5
Attitudes towards the benefits of TPSs (transaction processing systems)	F-67	0.28	1
Attitudes towards the benefits of DSSs (decision support systems)	F-68	0.43	1
Willingness to use IT available in company	F-69	0.29	1
Memories (folk memory) of past CVRS implementation failures	F-72	0.26	5

Table 6.25: Variables associated with *CVRS pre-attitude*

Despite the fact that the enlarged data set enables some variables significantly associated with **CVRS pre-attitude** to be identified, these will not be discussed in further detail. This has been decided, because **CVRS pre-attitude** considered in the *CVRS adoption model* relates to *CVRS decision makers* only[16]. In other words, the research intends to identify independent variables which, in the context of the adoption of CVRS technology, explain **CVRS pre-attitude** of exclusively *CVRS decision makers.*

Nevertheless, with view to the use of the model by future researchers the following section will outline the independent variables concerned.

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16 See Section 6.1, p. 140.

6.5.2 Presentation of variables

Company size: Polak [1988, p. 5] suggests that "potential users of CVRS appear to be intimidated by the scale of investment of time and resources that they anticipate will have to be made in the collection of the basic data associated with the introduction of CVRS". Moreover, large firms may be in a better position to justify expenditure on CVRS systems, for their cost saving potential will be comparatively high.

It is likely, therefore, that the company size and the associated size of financial and human resources is positively associated with CVRS pre-attitude.

IT policy in physical distribution: Due to its position within the final stage of the business process, the VRS function is often considered to be a relatively insignificant adjunct, the point at which rationalisation measures tend to stop. In many companies corporate IT investment is channelled into other "more important" areas [Polak, 1988, p. 3].

There is reason to believe, therefore, that individuals' pre-attitudes towards CVRS technology are influenced by the importance which their organisations' business policy allocates to the use of IT in general and the transport function in particular.

Organisational maturity: Ein-Dor and Segev [1981, p. 29] suggest that "The more mature an organisation, the greater its likelihood of successfully implementing MIS". The authors define mature organisations as formally organised, where the processes are well understood and quantifiable and data relevant to the organisation's management are available.

Findings from the current study's qualitative research suggest that potential users of CVRS are concerned about being unable to collect the distribution data required; areas of particular concern are geographical customer locations and average driving speeds on roads. Also, limited financial and human resources regularly represent major constraints on the implementation of software. Considerable savings in time and effort can be achieved if some of the CVRS data, in particular customer-related data, such as time windows and customer addresses, are readily available from, for example, existing fleet management software. There are grounds to believe, therefore, that organisational maturity is positively associated with CVRS pre-attitude.

Technological maturity: Peters and Doganis [1987] suggest that companies with a low level of automation or IT available (here referred to as "technological maturity"), tend to be dissuaded from adopting CVRS. Similar findings are reported by the CVRS suppliers revealing that many potential users feel "not ready" for the technology, as they lack or are in the process of implementing an adequate sales order processing or warehouse/stock control software system.

The lack of technological maturity causes concern that the company may be unable to efficiently use CVRS. This concern is likely to result in an unfavourable pre-attitude towards CVRS.

Individual differences: Ein-Dor and Segev [1981, p. 189] suggest: "The greater the perceived need for MIS and the lower the level of apprehension about them, the greater the likelihood of success". Gibson's [1975] study on systems implementation shows that prior attitudes are determined by both situational factors and personal variables. Bargl's [1994] recent study on CVRS has investigated the influence of some personal characteristics such as level of school education, professional training, computer literacy and experience with CVRS. However, as in Joseph's [1990] study on the acceptance of computer-aided design software, only the variable **school education** was found to have a significant association with the schedulers' acceptance of CVRS. Highly educated schedulers had the most favourable acceptance.

Individual differences can be categorised into three groups of variables:

- Cognitive style, decision behaviour, data processing behaviour [Lucas et al, 1990; Gross, 1989; Ramprasad, 1987; Organ and Bateman, 1986; Hysman, 1979; Zmud, 1979a, b; Witkin et al, 1971; Schroeder et al, 1967];
- Personality [Klauss and Jewett, 1974]; and
- Demographic and situational characteristics [Klauss and Jewett, 1974; Fürst and Cheney, 1982].

The analysis of cognitive styles and personality requires specialised psychometric tests such as the "16PF Test"[17] or the Myers-Briggs Type Indicator [Lucas et al, 1990] which are a complex and comprehensive evaluation procedures. Therefore, the current research focuses on demographic, interpersonal and situational variables as follows:

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[17] Institute for Personality and Ability Testing, Illinois.

- **School education:** Individuals with a high level of school education have theoretical computer knowledge and/or a good understanding of mathematical and technological principles.

  Since CVRS technology is based on complex mathematical programming, school education is expected to be positively associated with CVRS pre-attitude.

- **Variety of professional experience:** Individuals with a large variety of professional experience develop the ability to adapt themselves quickly to new work environments, including new work methods and technologies.

  These individuals are likely to have a favourable CVRS pre-attitude.

- **Computer literacy:** Individuals with experience and/or a good understanding of computers are more likely to possess a favourable CVRS pre-attitude.

- **Ability to evaluate costs and benefits of CVRS technology:** Interviews with CVRS suppliers reveal that many distribution managers feel unable to evaluate the precise costs, real benefits and consequences for the personnel and organisational structure arising from the use of CVRS technology. Similar findings were revealed by a survey on the use of distribution software, 60% of the firms interviewed could not quantify the costs associated with data collection or analysis [Wright and Cross, 1985]. At the same time, the companies felt that the cost of computer packages outweighed the benefits, despite having access to a personal computer.

  This inability to evaluate costs of CVRS is likely to provoke uncertainty which is expected to lead to a negative CVRS pre-attitude.

- **Consciousness of costs in physical distribution:** Wright and Cross [1985] suggest that the activities in the distribution division of some own-account operators are determined by policies which have little to do with the cost oriented operation of a vehicle fleet.

  This view is supported by the qualitative findings of the current research. The customer service level is strongly influenced by the sales/marketing function which aims to maximise sales with logistics costs frequently being insufficiently considered. Also, schedulers and drivers sometimes adopt a certain "cavalierattitude" by accepting unscheduled customer orders which do not cover the costs of their delivery.

It is expected, therefore, that the level of cost consciousness is positively associated with the pre-attitude towards CVRS.

- **General acceptance of DSSs:** The pre-attitude towards and perception of CVRSSs is strongly influenced by the general acceptance of DSSs. These are, compared to TPSs and MISs, prospective or externally oriented while the latter ones are retrospective or internally oriented[18] [Wright and Cross, 1985]. Companies mainly use IT as a means for pure data processing (e.g. sales order processing), information storage and supply (e.g. data base systems) as well as control (e.g. stock control systems). However, only very few companies use IT in the form of DSSs. They are generally more concerned with control rather than the management information which is made available by using DSSs.

  It is expected, therefore, that individuals with unfavourable attitudes towards DSSs are likely to have unfavourable pre-attitudes towards CVRS technology.

- **Folk memory of CVRSS failures:** Polak [1988, p. 7] suggests that "the road freight industry still retains a strong folk memory of the, sometimes spectacular, failures of early systems" (CVRSSs). Reasons for the failures were deficiencies in terms of the systems' underlying road network, planning algorithms and user friendliness. Moreover, many CVRSSs were designed to supplant the human scheduler [Polak, 1990]. Support for Polak's findings is available from the qualitative results of the current research, suggesting that individuals tend to remember previous bad experiences with early CVRS technology.

  It is likely, therefore, that unfavourable memories of early CVRSS failures lead to unfavourable CVRS pre-attitudes.

CVRS system quality: Individuals' pre-implementation attitudes towards CVRS technology are expected to be influenced by the quality of the particular packages investigated or experienced by individuals. Experience with CVRS packages of high quality are likely to lead to favourable CVRS pre-attitudes.

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[18] See Section 1.3.3 for definition of DSS, MIS and TPS , p. 7.

For methodological and practical reasons this research was unable to develop a valid measure for the quality of CVRS packages[19]. But even if such a measure were available, testing of the association between **CVRS system quality** and **CVRS pre-attitudes** would be difficult. Two important reasons for this are:

- Firstly, pre-implementation experiences with CVRS systems do not necessarily reflect the actual quality of the CVRS packages investigated. Only in-depth testing of the software applied to the potential users' individual distribution problems will allow for valid conclusions about the software and reveal its actual quality.

- Secondly, a large proportion of respondents to the survey did not have direct pre-implementation exposure to CVRS packages. Equally, some companies had exposure to more than one CVRS package and it is impossible to measure the effect of individual packages on the respondents' CVRS pre-attitudes.

As a result, the hypothesis concerning the relationship between **CVRS system quality and CVRS pre-attitude** will not be empirically validated in this study. Nevertheless, for the sake of completeness and with view to future research **CVRS system quality** will be presented as an integrative part of the *CVRS adoption model.*

The above factors form the following hypotheses:

Hypotheses 6a - 6l: The pre-implementation attitude towards CVRS technology is positively associated with the potential users':

- company size (*hypothesis 6a*);
- IT policy in physical distribution (*hypothesis 6b*);
- organisational maturity (*hypothesis 6c*);
- technological maturity (*hypothesis 6d*);
- school education (*hypothesis 6e*);
- variety of professional experience (*hypothesis 6f*);
- computer literacy (*hypothesis 6g*);
- ability to evaluate costs and benefits of CVRS technology (*hypothesis 6h*);
- consciousness of costs in physical distribution (*hypothesis 6i*);
- general acceptance of DDSs (*hypothesis 6j*);
- folk memory of CVRSS failures (*hypothesis 6k*); and
- experience with CVRS system quality (*hypothesis 6l*).

19 This issue will be further discussed in Sections 7.3.1 (p. 218f) and 7.3.3 (p. 223f).

6.5.3 Summary

Past research on MISs, DSSs and CVRSSs provides evidence that the users' attitude towards information technology is influenced by a variety of variables, in particular variables relating to individual differences. Using an enlarged data set of up to 143 respondents composed of both managers and schedulers, the current research was able to identify some relevant factors associated with **CVRS pre-attitude**. Overall, however, the study failed to provide significant evidence to explain which factors are associated with the **CVRS pre-attitude** of managers with *CVRS decision-making authority* as proposed by the present *CVRS model*. Future research intending to explain the role of CVRS pre-attitudes in the adoption process of CVRS may need to consider larger numbers of both current and potential CVRS users.

Due to the lack of a valid measure of **CVRS system quality** as well as methodological and practical problems involved in measuring its impact **CVRS pre-attitude**, the relationship between both variables has not been tested in this study.

6.6 Overview of main empirical findings

An organisation's decision to implement CVRS technology is influenced by two major factors: The awareness of CVRS ("**CVRS awareness**") and pre-implementation attitude towards CVRS ("**CVRS pre-attitude**").

CVRS awareness: Organisations using CVRS, compared with those not using CVRS, are significantly more aware of the software's existence and benefits as well as the development and progress made over recent years.

CVRS pre-attitude: Organisations using CVRS and those planning to use it in the near future have a significantly more favourable pre-implementation attitude towards the software than companies not using CVRS and not planning to use it in the near future.

Contrary to indications from past research, no evidence was found that the adoption of CVRS is associated with a firm's industrial relations. On the contrary, there is some qualitative evidence to suggest that unions have become more receptive to IT. Hence, the "union factor" appears to have become a less significant or no obstacle for the adoption of CVRS.

The critical **CVRS awareness** and **CVRS pre-attitude** factors have been further investigated to determine their cause. The major findings are:

CVRS awareness

- Large companies have a higher awareness of CVRS than small companies.
- Similarly, organisations with a highly centralised data processing function have a higher level of CVRS awareness than organisations where the data processing function has less formalised structures.
- CVRS suppliers are generally small organisations with limited financial and human resources. Their marketing activities are limited. It is not surprising, therefore, that firms learn most about CVRS via channels other than those used by the suppliers of the software.

CVRS pre-attitude

A number of variables were investigated to explain the pre-implementation attitude towards CVRS ("**CVRS pre-attitude**") of managers who decide on the implementation of CVRS technology. While the associations between **CVRS pre-attitude** and the independent variables generally were found to be positive or negative as expected, only a few associations were shown to be significant.

Figure 6.1 summarises all relationships between variables of the *CVRS adoption model* tested in the preceding sections. The relationships found to be significant and non-significant are indicated by continuous lines and dashed lines respectively. Subsequent Table 6.26 summarises the hypotheses relating to the significant relationships.

Note that in Figure 6.1 the relationships expressed by *hypotheses 6a to 6k* are indicated as non-significant (dashed line), despite some variables being found significant when tested with an enlarged data including all managers and, for certain variables, all schedulers. Nevertheless, the identified significant associations are disregarded, because the **individual differences** variables in the *CVRS adoption model* are related to managers with *CVRS decision-making authority* only. Note also that the relationship between **CVRS system quality** and **individuals' CVRS pre-implementation attitude** marked with a dotted line has not been tested empirically in the current study[20].

[20] See Section 6.5.2, pp. 176-177.

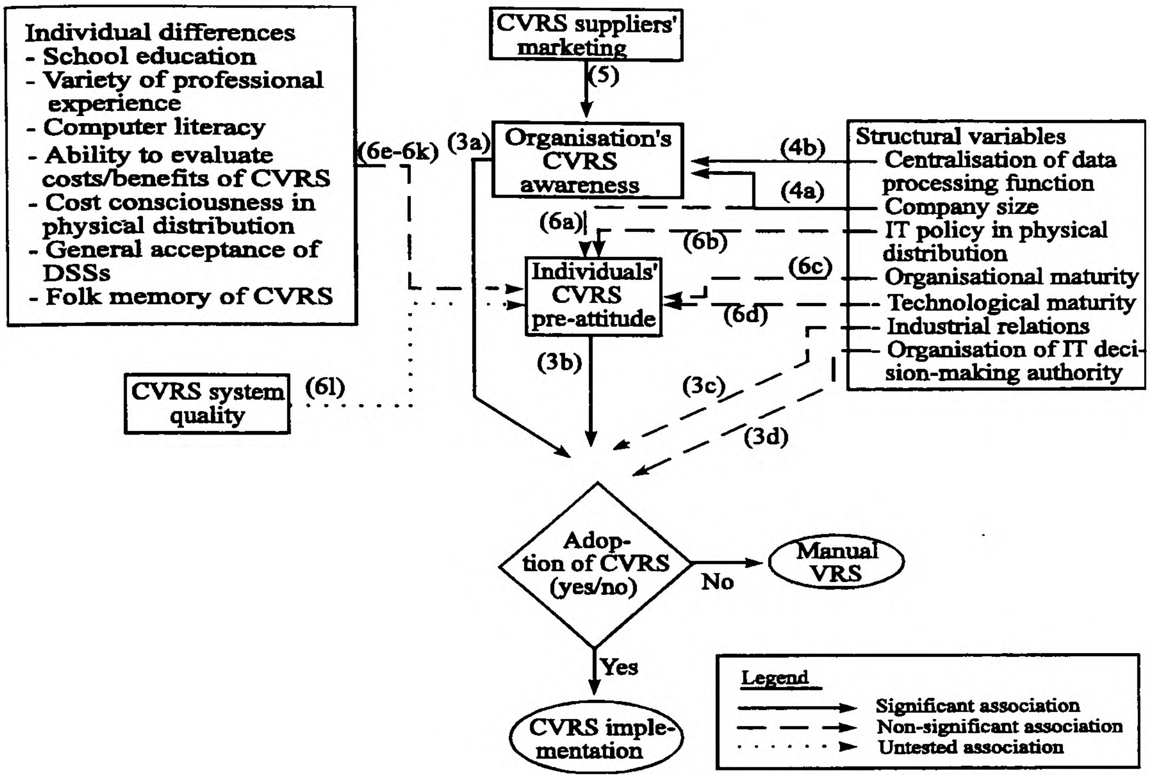

Figure 6.4: Overview of significant and non-significant relationships of the CVRS adoption model

	Hypotheses relating to the *CVRS adoption model*	**significance level[1] (p in %)**
3a	The adoption of CVRS technology is positively associated with the potential users' awareness of the software.	1, 5[2]
3b	The adoption of CVRS technology is positively associated with the potential users' pre-attitude towards the software	1, 5, 10[2]
4a	The awareness of CVRS technology is positively associated with the potential users' company size	1, ns
4b	The awareness of CVRS technology is positively associated with the potential users' centralisation of the data processing or similar service function	1, 5
5	The software suppliers' marketing activity has not led to a significant awareness of CVRSSs available.	significant[3]

[1] A hypothesis can have ***several significance levels*** if it is composed of several dimensions or sub-dimensions. If the majority of dimensions or sub-dimensions of a concept show significant findings, then the non-significant findings will be ignored in this table. Similarly, if the dimensions or sub-dimensions of concepts have equal numbers of significant and non-significant findings, the non-significant findings will be ignored if there is a preponderance of dimensions or sub-dimensions labelled *important* ("+") which are found to be significant.

[2] The significance levels refer to the second classification variable relating to "current and future users/non-users of CVRS"; compare Section 6.3.3, pp. 155 .

[3] The hypothesis was tested with univariate statistics as opposed to bivariate statistics. Therefore, no significance level in terms of "p" was available.

Table 6.26: Significant hypotheses relating to the *CVRS adoption model*

Chapter 7: Factors Associated with the Success of CVRS

7.1 Introduction

This Chapter investigates the factors which explain the success of CVRS technology with regard to both the implementation and the subsequent use of the software. The relationships between the variables investigated are illustrated in Figure 7.1 showing the *CVRS success model.*

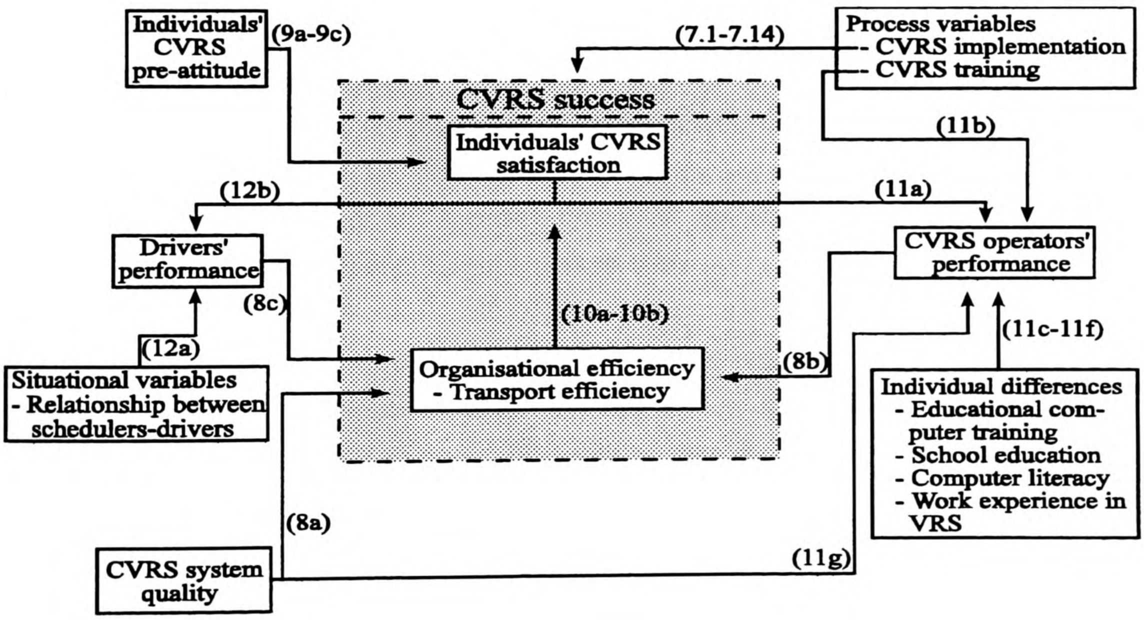

Figure 7.1: CVRS success model

As with the *CVRS adoption model* the *CVRS success model* is conceptually factor-oriented as opposed to process-oriented. An exception to this is the conceptualisation of **CVRS system implementation**. Despite looking at **CVRS system implementation** retrospectively (i.e. after the implementation has taken place), the research aims at capturing the dynamics of the process in terms of several key process attributes and relationships using the evidence provided by the in-depth case studies. In addition, evidence supplied by the survey is used to provide quantitative support for the relationships between the implementation variables (factors) concerned.

The model's foundations are largely laid on the early exploratory work of Lucas [1973, 1975, 1976, 1978]. He was among the first researchers to invoke organisational factors rather than technical ones to explain the failure of information systems and to suggest actions to prevent their continued failure.

The basic structure of the *CVRS success model* is also been strongly influenced by the work of Ives et al [1980]. The authors developed a *framework of research in computer-based management information systems* which is based on the thought of Lucas. The model of Ives and his co-researchers also includes the work of Mason and Mitroff [1973] as well as Chervany et al [1971].

The above work of Lucas and Ives et al is of particular relevance to the current research, because of its broad perspective covering a wide range of classes of variables. In contrast, much of the more recent empirical information system literature as identified in the current research[1] has focused on fewer but more specific research aspects of MISs/DSSs, often related to specific types of software, rather than taking a comprehensive and thus general research perspective.

An exception to this is the recent empirical study of Lucas et al [1990] which puts forward a two-stage *structural model* of information system implementation. The authors consider their model to be an extension of previous information system models. The latter are described as having largely "looked at direct relationships between individual explanatory variables and implementation outcomes, primarily use and satisfaction" [1990, p. 34]. Therefore, Lucas et al suggest "that a chain of intermediate variables can be specified to constitute an integrated, and we think, more realistic, model of implementation" [1990, p. 34]. Overall, this *structural model* is "quite complex and testing it is a difficult task" [Lucas et al, 1990, p. 90]. Therefore, it has only a limited input in the development of the author's *CVRS models*.

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1 For example: Rao and Jarvenpaa [1991], Hiltz and Johnson [1990], Doll and Torkzadeh [1989], Dos Santos [1989], Dos Santos and Bariff [1988], Sharda et al [1988], Cats-Baril and Huber [1987], Davis et al [1987], DeSanctis and Gallupe [1987], Kendall et al [1987].

In this research **CVRS success**[2] is defined at its *macro level* by the **organisational efficiency** concept and at its *micro level* by the **CVRS user satisfaction** concept. The two concepts are believed to be associated with each other in such a way that **organisational efficiency** influences **CVRS user satisfaction**. In other words, CVRSSs which facilitate the generation of cost effective routes are likely to lead to satisfied users (with *users* referring to the system operators, drivers and their managers). This approach suggests that the two concepts of **CVRS success** should be analysed separately in relation to their association with other concepts. To perform such analysis, **organisational efficiency** and **CVRS user satisfaction** need to be reconsidered for operationalisation as shown below.

7.1.1 Operationalisation of concepts

Organisational efficiency

At the outset of the current research it was hoped to investigate the association between the independent variables and each dimension of **organisational efficiency,** these being **transport efficiency**, **efficiency of VRS procedure**, **efficiency of warehouse procedure** and **various intangible benefits.** However, the approach has turned out to be invalid for two major reasons as discussed below:

Firstly, the actual extent to which the use of CVRS technology affects the above dimensions of **organisational efficiency** varies according to the operating sites' original level of efficiency prior to the software's introduction. Some sites may initially have been better organised and more strictly controlled than others. Moreover, some sites had used some computer support in VRS, while other sites had applied manual planning techniques only. Thus, previously efficient sites with consequently low relative cost savings achieved from the application of CVRS would appear to be unsuccessful, while initially less efficient sites with high relative cost savings would appear to be successful. Also, at some sites CVRS may have enhanced **organisational efficiency** exclusively by a reduction in mileage, while at other sites the vehicle fleet size was reduced. The latter may have been achieved by an increase in vehicle utilisation by time and/or weight (volume).

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2 See Figure 3.1, p. 59.

Secondly, the independent variables investigated in this research, which are believed to influence **organisational efficiency,** are operationalised in general terms. Therefore, they are unable to fully explain why some sites achieve higher levels of efficiency than others. More in-depth studies and associated refined measurement techniques are required to identify and evaluate the extent to which independent variables affect the individual dimensions of **organisational efficiency**. Such studies ideally need to accompany the CVRS projects through all their stages, including the systems' implementation and subsequent use as well as the assessment of the users' initial level of efficiency in VRS.

Consequently, for the testing of the hypotheses within this Chapter, **organisational efficiency** is operationalised in general terms; that is, successful CVRSSs lead to transport cost savings, while unsuccessful CVRSSs fail to do so (Table 7.1). This general measure takes account of the above problem, in that it does not measure the extent to which CVRS enhances **organisational efficiency**, but whether or not an increase in **organisational efficiency** has occurred.

Concept	Dimension	Indicator (contents)	Indicator (label)
Organisational efficiency	(not applicable)	CVRS reduces/fails to reduce transport costs	G-187

Table 7.1: Operationalisation of the *organisational efficiency* concept in general terms

CVRS user satisfaction

The **CVRS user satisfaction** concept was previously operationalised in Table 3.8[3]. It includes various sub-dimensions covering individuals' general satisfaction as well as various specific aspects of satisfaction with the software or changes induced by the software.

As this Chapter investigates the associations between variables operationalised in rather general terms (e.g. general **CVRS pre-attitude**, **organisational efficiency** in general, general **computer experience**), **CVRS user satisfaction** also needs to be operationalised in general terms. A concept of **CVRS user satisfaction** in general terms is developed for each group of CVRS users, these being managers, schedulers and drivers (Table 7.2).

3 See Table 3.8, p. 88; see also Section 3.3.3.2, p. 87f.

Concept	Dimension	Indicator (contents)	Indicator (label)
Managers' CVRS satisfaction	(not applicable)	+ Overall satisfaction with CVRS + General happiness about company's use of CVRS + General usefulness of CVRS for company's requirements + Retrospective support of CVRS implementation + Overall superiority of CVRS compared to manual VRS + Ability of CVRS to meet overall requirements in distribution + Ability of CVRS to meet daily transport requirements	H-1m (index)
Schedulers' CVRS satisfaction	(not applicable)	+ Overall satisfaction with CVRS + General happiness about company's use of CVRS + General usefulness of CVRS for company's requirements + Retrospective support of CVRS implementation + Overall superiority of CVRS compared to manual VRS + Ability of CVRS to meet overall requirements in distribution + Ability of CVRS to meet daily transport requirements	H-1s (index)
Drivers' CVRS satisfaction	(not applicable)	+ Overall satisfaction with CVRS + General happiness about company's use of CVRS + General usefulness of CVRS for company's requirements + Retrospective support of CVRS implementation	H-1d (index)

Table 7.2: Operationalisation of the *CVRS user (manager, scheduler, driver) satisfaction* concepts in general terms and formation of general *CVRS satisfaction* indices

The indicators of **CVRS user satisfaction** correlate highly at the 1% significance level within each user group relating to managers, schedulers and drivers. Therefore, the indicators are averaged to form a **CVRS user satisfaction index** for each group as shown in the previous Table 7.2.

Concepts expected to be associated with **CVRS success** will be presented in Sections 7.2 to 7.6.

Section 7.2 will discuss the independent variable **CVRS implementation** which is extremely complex, comprising several dimensions and sub-dimensions. The influence of **CVRS implementation** on **CVRS success** is investigated from a broad perspective as opposed to the strictly separate **organisational efficiency** concept and the **CVRS user satisfaction** concept. The analysis is based on predominantly qualitative evidence provided by the case studies and expert interviews. In addition and, where appropriate, the findings are supported by quantitative evidence obtained from the survey. The use of qualitative or "rich" evidence enables **CVRS success** to be analysed from a broader perspective than is possible on the basis of quantitative evidence only.

Section 7.3 will discuss further independent variables with respect to their impact on **organisational efficiency.** Similarly, Section 7.4 will discuss further independent variables with respect to their impact on **CVRS user satisfaction**.

Sections 7.5 and 7.6 will extend the scope of the investigation. Those independent variables which will be identified as having an impact on **organisational efficiency** and **CVRS user satisfaction** will be analysed in relation to their cause. Hence, variables which in section 7.3 and 7.4 are treated as independent variables (**CVRS operators' performance**; **drivers' performance**) will then be treated as dependent variables. The aim will be to identify those independent variables which explain the then dependent variables.

7.1.2 Reliability and validity of measurement

The above **CVRS user satisfaction** indices of managers (indicator: H-1m), schedulers (indicator: H-1s) and drivers (indicator: H-1d) are considered reliable and valid measures as substantiated below:

R*eliability* or *internal consistency* of the index-measures is emphasised by high *Cronbach Alpha coefficients* which are all well above the minimum level of 0.8 (Table 7.3).

CVRS user satisfaction index	Cronbach Alpha Coefficient
Managers' CVRS satisfaction index	0.93
Schedulers' CVRS satisfaction index	0.81
Drivers' CVRS satisfaction index	0.89

Table 7.3: Cronbach Alpha coefficient for testing the reliability of *CVRS user satisfaction* indices

Construct validity of the indices is emphasised by *factor loading* substantially higher than the minimum score of 0.6. Further support is given by the overall high correlation (total score correlation) between individual indicators and the sum of the other indicators. All correlations are significant at the 1% level (Table 7.4 - 7.6).

Indicators of managers' CVRS satisfaction index	Factor loading	Total score correlation	p %
+ Overall satisfaction with CVRS	0.90	0.74	1
+ General happiness about company's use of CVRS	0.79	0.52	1
+ General usefulness of CVRS for company's requirements	0.80	0.55	1
+ Retrospective support of CVRS implementation	0.91	0.69	1
+ Overall superiority of CVRS compared to manual VRS	0.79	0.59	1
+ Ability of CVRS to meet overall requirements in distribution	0.88	0.78	1
+ Ability of CVRS to meet daily transport requirement	0.86	0.79	1

Table 7.4: Factor analysis and total score correlation for testing construct validity of the *managers' CVRS satisfaction* index

Indicators of schedulers' CVRS satisfaction index	Factor loading	Total score correlation	p %
+ Overall satisfaction with CVRS	0.85	0.80	1
+ General happiness about company's use of CVRS	0.83	0.58	1
+ General usefulness of CVRS for company's requirements	0.82	0.67	1
+ Retrospective support of CVRS implementation	0.81	0.65	1
+ Overall superiority of CVRS compared to manual VRS	0.80	0.71	1
+ Ability of CVRS to meet overall requirements in distribution	0.85	0.73	1
+ Ability of CVRS to meet daily transport requirement	0.83	0.81	1

Table 7.5: Factor analysis and total score correlation for testing construct validity of the *schedulers' CVRS satisfaction* index

Indicators of drivers' CVRS satisfaction index	Factor loading	Total score correlation	p %
+ Overall satisfaction with CVRS	0.85	0.74	1
+ General happiness about company's use of CVRS	0.92	0.85	1
+ General usefulness of CVRS for company's requirements	0.88	0.76	1
+ Retrospective support of CVRS implementation	0.90	0.77	1

Table 7.6: Factor analysis and total score correlation for testing construct validity of *drivers' CVRS satisfaction* index

7.2 Associations between CVRS implementation and CVRS success

7.2.1 Introduction

The implementation of IT systems in conservative environments such as physical distribution, in particular road transport, is usually no easy task. Strong opposition from the schedulers and, even more so, from the drivers needs to be anticipated. Moreover, the implementation of CVRS software is a lengthy and complex process, which usually requires large amounts of human and material resource. Finally, CVRS is a complex technology in itself, comprising many parameters which need to be carefully tuned in accordance with users' individual requirements.

7.2.2 Past research

The basic elements of the **CVRS implementation concept** used in the current research have been largely identified from the early studies on the implementation of information systems (subsequently referred to as "*system implementation*"). These studies investigated the implementation and use of information systems from a rather general or exploratory perspective. Much emphasis was placed upon "what" relationships exist between information system variables rather than explaining the cause of the relationships as pursued by the more recent research [Cooper, 1988].

Previous studies have suggested that *system implementation* should be viewed as a process of organisational change [Zand and Sorensen, 1975; Ginzberg, 1979; Ginzberg, 1981a]. According to these studies successful system implementation is positively correlated with the quality of the implementation process. Successful projects were found to have a preponderance of favourable forces in each phase of the implementation.

The *Schein model of planned individual change* [Schein, 1961; Schein, 1972], which is an extension of the dynamic change model developed by Lewin [1952], views change as a process comprising three general phases:

- Unfreezing (creating the motivation to change);
- Moving (developing new ideas, attitudes, values and behavioural patterns); and
- Refreezing (stabilising and integrating newly established changes into the rest of the system).

Zand and Sorensen [1975] have tested the Lewin/Schein model via a questionnaire survey using a large sample of management scientists. The authors conclude that there is a positive correlation between high levels of activity conducive to the model's **unfreezing, moving** and **refreezing** stages and system success.

The *Kolb/Frohman approach to consulting* [Kolb and Frohman, 1971] divides the process of change into seven phases: (1) Scouting, (2) Entry, (3) Diagnosis, (4) Planning, (5) Action, (6) Evaluation and (7) Termination. Ginzberg's [1979] study on implementation processes is based on the Kolb/Frohman model with the Lewin/Schein model as the underlying theory. He suggests that users in successfully implemented projects report significantly better handling of the process of change than do users in unsuccessful projects. As in Zand and Sorensen's study, the strongest differences were found at the Termination or Refreezing stage.

The above evidence of past research on *system implementation* in general and findings on the applied use of CVRS [Holmes, 1989; Hooban and Jones, 1993] suggest that effective implementation strategies are required to ensure that CVRS projects are successful.

7.2.3 Presentation of variables

The Lewin/Schein model is very general and is judged inappropriate to be operationalised for the current research. However, the basic theory of the model has been helpful in defining operationally the activities necessary for the process of change in the implementation of CVRSSs. A more appropriate approach for analysing the impact of the implementation process on the success of CVRS technology is the Kolb/Frohman model of the consulting process as used by Ginzberg's study on the implementation process. Associated with each phase of the model are "certain issues which should be resolved before the process moves on to the next phase" [Ginzberg, 1979, p. 89]. The Kolb/Frohman model has strong analogies with the process of organisational change induced by the implementation of new systems or projects, in particular the implementation of complex software systems which affect individuals in various business functions.

Nevertheless, like the Schein/Levin model, the Kolb/Frohman model views change predominantly as social change - a process relating to individuals' perceptions, attitudes and behaviour or the "human factor". The model ignores the more complex sub-dimensions of the implementation of CVRSSs which also include factors of change relating to non-human factors or variables, for example, testing the software, planning and organising the collection of distribution data and keeping data up-to-date. Therefore, the CVRS implementation concept of the current research uses the Kolb/Frohman model as the underlying basic framework but extends it along a number of CVRS-specific sub-dimensions (Table 7.7). Further detail on the concept's components is available in Section 7.2.5.2, which also presents the results for validating the concept or model.

Dimensions (Kolb/Frohman stage)	Sub-dimensions
Diagnosis	Informing the staff about the planned CVRS project at an early stage
	Analysing physical distribution to determine information requirements of CVRS
	Testing the CVRS system with historical data
Planning	Defining an implementation plan
Action	Demonstrating top-management support
	Appointing a project leader with decision-making authority and technical competence
	Involving the system operators and drivers in the implementation process
	Developing conviction, commitment and ambition to succeed in the project on the part of the managers, schedulers, drivers
	Training of system operator
	Collecting, inserting and validating the software's distribution data
	Adjusting customer delivery constraints to increase route efficiency
Evaluation	Assessing how well the initially defined objectives have been met. Applying corrections as appropriate
Termination	Transferring the CVRS system "ownership" and responsibility to the system operators
Post implementation	Keeping distribution data and associated software parameters up to date

Table 7.7: *CVRS implementation* concept with the Kolb/Frohman model as underlying framework

The variables in the above implementation concept or model form the following general hypothesis:

***Hypothesis 7*:** CVRS success is related to a preponderance of favourable forces in each phase of the implementation process.

Each sub-dimension of the implementation concept is analysed individually with respect to **CVRS success**. As a result, the general *hypothesis 7* is further specified by sub-hypotheses (Table 7.8).

Kolb/ Frohm. stage	CVRS implementation sub-hypotheses
Diag-nosis	**7.1:** Informing and actively preparing the scheduler, drivers and staff in related business functions for the planned CVRS project facilitates the software's implementation, as it helps to avoid individuals' and their union representatives' feelings of unease or, at the most extreme, rejection of the project.
	7.2: A highly detailed analysis of the CVRS users' distribution environment with the aim of identifying the actual information requirements of CVRS is positively associated with CVRS success.
	7.3: In-depth testing of the CVRSS using distribution data of past periods allows for the selection of a CVRSS appropriate to the users' actual requirements.
Plan-ning	**7.4:** Thorough planning and organisation of the CVRSS's implementation, ensuring that all required human and technical resources are available at the right place and right point in time, is positively associated with CVRS success.
Action	**7.5:** Top-management support for the CVRS project is positively associated with CVRS success.
	7.6: The availability of centralised responsibility through a project leader during the software's implementation is positively associated with CVRS success. This effect is greatest if the project leader possesses technical competence and decision-making authority given by his/her status at a high level in the organisation.
	7.7: Involvement of schedulers and drivers in the system's implementation is positively associated with CVRS success.
	7.8: Involvement of schedulers and drivers in the system's implementation is positively associated with favourable feelings (satisfaction) arising from the feeling of being part of the implementation project.
	7.9: Individuals' convictions about the success of and commitment to the CVRS project are positively associated with CVRS success.
	7.10: Accurate collection, input and validation of distribution data are positively associated with CVRS success.
	7.11: Changing customer-related delivery constraints, such as time windows and delivery frequencies, in order to increase the effectiveness of VRS, is positively associated with CVRS success.
Evalu-ation	**7.12:** The effort spent on assessing how far initially-set objectives have been met and, in the case of deviations, adjusting the system accordingly, is associated with CVRS success.
Termi-nation	**7.13:** The transfer of system "ownership" and responsibility to the system operators is positively associated with CVRS success.
Post imple-menta-tion	**7.14:** Constantly adjusting the distribution data in accordance with changes in the distribution environment is positively associated with CVRS success.

Table 7.8: Sub-hypotheses 7.1 - 7.14 relating to CVRS implementation and CVRS success concepts

7.2.4 Measurement of variables

Operationalisation of concepts

Table 7.9 shows the operationalisation of the **CVRS implementation** concept. The table is further described below.

Dimension (Kolb/ Frohman stage)	**Sub-dimension**	**Indicator (contents)**	**Indicator (label)**
A	**C**	**D**	**E**
Diagnosis	Staff information	Informing scheduler and drivers about the CVRS implementation at an early stage	I-127 I-128
	Analysis	Analysing physical distribution environment Analysing CVRS compatibility with work procedures	I-119 I-120
	CVRSS test	Testing CVRSSs with actual distribution data	#
Planning	Implementation plan	Quality of software's implementation plan/organisation	I-121
Action	Top-management support	Top-management support for CVRS project	I-123
	Project leader	Availability of CVRS project leader Project leader's possession of decision-making authority Project leader's possession of technical competence	I-124 I-125 I-126
	Involvement	Involving schedulers in the CVRS project Involving drivers in the CVRS project	I-129 I-130
	Conviction, commitment and ambition	Managers' convictions about the CVRS system's success Schedulers' convictions about the CVRS system's success Drivers' convictions about the CVRS system's success Managers' commitment to/ambition for the CVRS project Schedulers' commitment to/ambition for the CVRS project Drivers' commitment to/ambition for the CVRS project	I-132 I-133 I-136 I-134 I-135 I-137
	CVRS data handling	Collecting, inserting and validating distribution data	I-143
	Adjusting CVRS parameters	Adjusting delivery parameters, e.g. delivery times, delivery frequencies etc.	I-144
Evalua-tion	Target assessment	Assessing how objectives have been met	I-145
	Target correction	Implementing corrections in case of deviations from objectives	I-146
Termina-tion	System ownership/ responsibility	Transferring the CVRSS "ownership" to the schedulers' responsibility	I-147
Post imple-mentation	Update of data and parameters	Extent of keeping data/parameters up to date	I-148

Sub-dimensions which were measured by the case studies only. Therefore, no clearly formulated indicator is available

Table 7.9: Operationalisation of the *CVRS implementation* concept

Because of its exploratory function of taking an overall and wide research perspective, the case study and expert interview research investigate the **CVRS implementation** concept and associated (sub-)dimensions in broad terms. The indicators shown in column D of Table 7.9 have been used as a guide line for structured face-to-face interviewing. In contrast, the survey is based on clearly formulated questions (indicators) and the use of scales as indicated by the designations of the indicators in column E of Table 7.9.

The **CVRS success** concept is operationalised specifically for each of the current study's sources of data collection as follows:

Case studies and expert interviews

In the case study and expert interview research **CVRS success** is operationalised in such a way that **CVRS success** results in the continuous use of the software, while **system failure** results in the software's abandonment (Table 7.10).

Concept	Dimension	Indicator
CVRS success	Use of CVRS system	Continued use or abandonment of CVRS
	Individuals' reactions	Individuals' feelings, attitudes and support during CVRS implementation
	CVRS selection	Selecting the CVRSS appropriate to requirements

Table 7.10: Operationalisation of the *CVRS success* concept in the case study and expert interview research

For certain sub-hypotheses, **CVRS success** is specified by the **individuals' reactions** dimension which is measured by the "individuals' feelings, attitudes and support demonstrated during CVRS implementation" indicator. Finally, for one sub-hypothesis **CVRS success** is specified by the **CVRS selection** dimension which is measured by the "selecting appropriate CVRSSs which meet the users' actual requirements" indicator.

Survey

In the survey research **CVRS success** is defined in terms of general **organisational efficiency** which is operationalised as whether or not CVRS **directly** leads to a reduction in transport costs[4].

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[4] See Table 7.1, p. 184.

Definition of scales

Regarding the survey, all dimensions and associated sub-dimensions of the **CVRS implementation** concept used are measured by indicators based on a *semantic differential seven-point scale*.

The **use of CVRS system** dimension relating to CVRS success in the case study and expert interview research, is measured by an indicator based on a nominal scale with the categories "continued use of CVRS" or "abandonment of CVRS".

The **individuals' reactions** dimension is measured by indicators which are mainly based on a *semantic differential seven-point scale*. However, some indicators used in the case studies and expert interview research are not based on any clearly defined scale. Instead, the indicators have been used as a guideline for data collection.

CVRS success in terms of the **organisational efficiency** concept used in the survey research is measured by an indicator based on a nominal scale allowing for the response "transport cost savings" or "no transport cost savings".

Data analysis

The findings obtained from the survey research are based on responses of 39 CVRS system installations, with the actual number of responses depending on the individual questionnaire items (indicators) concerned. All responses were given by managers only. Responses of schedulers are not considered for three reasons:

- Firstly, the available sample of schedulers who were involved in the implementation is too small to obtain meaningful statistical results. The number of responses to the particular implementation variables varies, depending on the individual dimensions or sub-dimensions and their indicators concerned, between 8 and 20.

- Secondly, the sample does not include all schedulers involved in the software's implementation at individual distribution sites. Results based on an arbitrary selection of schedulers' responses are likely not to reflect the actual picture of the software's implementation.

- Finally, not all schedulers of those included in the survey were equally involved in the software's implementation.

Consequently, the schedulers' perceptions or evaluations of the implementation and their contribution to the overall implementation vary, depending on the length and degree of involvement in the implementation process. At the most extreme, in particular at sites with more than one scheduler, some schedulers were involved only to a marginal extent while specially-appointed schedulers carried out most of the implementation. This suggests that the schedulers' responses to the implementation items ought to be considered as unreliable. This assumption is supported by the fact that several schedulers from the same sites gave different responses to the same implementation variable.

Hence, data concerning the schedulers and drivers in relation to aspects of the software's implementation are supplied by the managers. These responded with regard to the individuals involved in the CVRS implementation project as an average.

The proposed associations tested by the survey are analysed using the *Kruskal-Wallis procedure*.

7.2.5 Results

7.2.5.1 Overview of results

The evidence provided by this research overall supports the combined *hypothesis 7* stating that successful implementation of CVRS projects is related to a preponderance of favourable forces in each phase of the implementation.

Regarding the direction of the causal relationship, the measures of **CVRS implementation** precede **CVRS success** in time. Therefore, the measures of **CVRS implementation** contribute to **CVRS success**.

The results are presented in the following Tables 7.11 to 7.13.

Table 7.11 summarises findings of past empirical studies on the implementation of MIS and DSS in general; they have been categorised according to each sub-dimension of the current CVRS implementation concept.

Sub-hypothesis	CVRS implementation		Past empirical research
	Dimension	Sub-dimension	
A	B	C	D
7.1	Diagnosis	Staff information	Guise 1987; Bell et al 1983; Burnes, 1992; Hooban & Jones, 1993
7.2		Analysis	McKeen, 1983
7.3		CVRSS test	
7.4	Planning	Implementation plan	Ginzberg, 1981a; Meador et al, 1984
7.5	Action	Top-management support	Schein, 1961, 1972; Lucas, 1974; Schulz and Slevin, 1975; Meador et al, 1984; Sanders and Courtney, 1985; Lucas et al, 1990.
7.6		Project leader	Edström, 1977; Welsch, 1981; Maisch, 1979; Lucas, 1976; Zielinski, 1984; Eastburn and Christensen, 1986
7.7 7.8		Involvement	Ives and Olson, 1984; Zielinski, 1984; Baroudi et al, 1986; Eastburn and Christensen, 1986, Lucas et al, 1990
7.9		Conviction, commitment and ambition	Ginzberg, 1981a; Burnes, 1992
7.10		CVRS data handling	Zielinski, 1984
7.11		Adjusting CVRS parameters	
7.12	Evaluation	Target assessment/correction	
7.13	Termination	CVRSS "owner-ship"/ responsibility	Schein, 1961; Ginzberg, 1979; Zand and Sorensen, 1975; Ginzberg, 1981a
7.14	Post implementation	Updating CVRS data and parameters	

Table 7.11: Summary of past empirical research in relation to *hypothesis 7*

Table 7.12 summarises the empirical findings on associations between dimensions or sub-dimensions of **CVRS implementation** and **CVRS success** provided by the case studies and survey of the current research.

Sub-hypothesis	CVRS implementation		Evidence from current research		
	Dimension	Sub-dimension	Evidence from case study	Evidence from survey: Indicator (label)	Evidence from survey: Sign. level (p in %)
A	B	C	D	E	F
7.1	Diagnosis	Staff information	Yes	#	#
7.2		Analysis	Yes	I-119 I-120	**10** **10**
7.3		CVRSS test	Yes	#	#
7.4	Planning	Implementation plan	Yes	I-121	**1**
7.5	Action	Top-management support	Yes	I-123	**10**
7.6		Project leader	Yes	I-124 I-125 I-126	ns **5** ns
7.7 7.8		Involvement	Yes	I-129 I-130	ns ns
7.9		Conviction, commitment and ambition	Yes	I-132 I-133 I-136 I-134 I-135 I-137	**1** **5** **10** **5** **1** **5**
7.10		CVRS data handling	Yes	I-143	ns
7.11		Adjusting CVRS parameters	Yes	#	#
7.12	Evaluation	Target assessment/correction	Yes	I-145 I-146	**10** ns
7.13	Termination	CVRSS "ownership"/responsibility	Yes	#	#
7.14	Post implementation	Update of data and parameter	Yes	I-148	**1**

\# Sub-dimensions which were unsuitable for measurement by the survey

Table 7.12: Summary of findings from the current research on *hypothesis 7*

Table 7.13 shows the survey results obtained from the *Kruskal-Wallis procedure* in further detail[5].

Independent variable		**Dependent variable**		
Indicators of "CVRS Implementation" (contents)	**Indicator (label)**	**CVRS Success (Transport cost savings)**		
		Savings (SS[1]) Rank	**No savings (US[2]) Rank**	**p %**
Analysing physical distribution environment	I-119	14.1	8.7	**10**
Analysing CVRS compatibility with work procedures	I-120	14.9	8.8	**10**
Quality of CVRS implementation plan/organisation	I-121	18.6	7.3	**1**
Top-management support for CVRS project	I-123	17.9	10.5	**10**
Availability of CVRS project leader	I-124	13.1	9.6	ns
Project leader's possession of decision-making authority	I-125	12.6	6.5	**5**
Project leader's possession of technical competence	I-126	11.5	8.8	ns
Involving schedulers in the CVRS project	I-129	14.4	12.4	ns
Involving drivers in the CVRS project	I-130	15.9	16.4	ns
Managers' convictions about CVRS system's success	I-132	18.2	9.1	**5**
Schedulers' convictions about CVRS system's success	I-133	16.1	7.0	**5**
Drivers' convictions about CVRS system's success	I-136	17.4	10.4	**10**
Managers' commitment to/ambition for the CVRS project	I-134	18.1	9.8	**5**
Schedulers' commitment to/ambition for the CVRS project	I-135	16.3	6.2	**1**
Drivers' commitment to/ambition for the CVRS project	I-137	18.3	8.6	**5**
Collection, inserting and validating distribution data	I-143	18.2	14.3	ns
Assessing how objectives have been met	I-145	16.9	9.8	**10**
Implementing corrections if deviations from objectives	I-146	12.7	11.8	ns
Extent of keeping data/parameters up to date	I-148	21.3	9.7	**1**

[1] SS = Successful systems, i.e. systems which <u>managed</u> to achieve transport cost savings

[2] US = Unsuccessful systems, i.e. systems which <u>failed</u> to achieve transport cost savings

Table 7.13: Kruskal-Wallis test of indicators relating to hypothesis 7

Past research

Except for certain CVRS-specific implementation sub-dimensions such as **keeping parameters and associated software parameters (of CVRSSs) up to date**, <u>all</u> of the implementation sub-hypotheses were initially substantiated by evidence of past empirical studies on the implementation of DSSs and MISs in general (Table 7.11).

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[5] Further detail is also available in Table A2-5 (Appendix 2), p. A-30

Case studies

The qualitative and rich evidence obtained from the in-depth case studies of the current research support all of the implementation sub-hypotheses (Table 7.12: column D). Successful CVRS installations (i.e. systems which were used continuously as opposed to having been abandoned) handled the implementation issues or variables more effectively than unsuccessful CVRSS installations (i.e. systems which were abandoned)

Survey

Overall, support for the implementation sub-hypotheses is also provided by the survey (Table 7.12: column E, F and Table 7.13).

More than two-thirds of the 19 implementation variables tested showed significant differences between successful CVRS installations (SS: systems which lead to transport costs savings) and unsuccessful CVRS installations (US: systems which fail to lead to transport costs savings) at the 1% 5% or 10% level; that is,

- 3 are significant at the 1% level,
- 5 are significant at the 5% level; and
- 5 are significant at the 10% level.

Successful CVRS installations (SS) have higher average rankings with respect to the implementation issues than unsuccessful CVRS installation (US), (Table 7.13). This suggests that the implementation dimensions or sub-dimensions were handled more favourably in successful CVRSS installations than in unsuccessful CVRSS installations.

The survey analysis excluded associations concerning three implementation sub-dimensions as outlined below:

- Staff information: Contrary to what was initially assumed during the survey's design, the sub-dimension **staff information** has no direct association with the success variable **organisational efficiency** by which the survey research measures CVRS success. Instead, staff information is assumed to be associated with the variable **individuals' reactions** measured in terms of "individuals' feelings (satisfaction), attitudes and support during the implementation process". No such measures are available from the survey research. Further quantitative analysis is required, preferably accompanying the software's implementation process during its various stages. Such analysis would aim to assess the impact which staff information in terms of early informing about the planned change has on individuals' initial reactions and subsequent implementation behaviour.

- Adjusting delivery parameters: Contrary to what was initially assumed during the survey's design, the majority of distribution sites investigated in the survey do not perform adjustments of delivery parameters such as delivery time-windows or order frequencies. Since such adjustments are of strategic-tactical nature, they are mainly made by the centralised management functions at higher levels using specialised strategic and tactical CVRSSs. Consequently, the survey is found to be unable to measure this particular sub-dimension of **CVRS implementation.**

- System ownership/responsibility: The survey largely includes responses of sites with usually one main scheduler and/or several secondary schedulers. The system ownership tends to be allocated to the main scheduler. However, since the responses to the survey were given by the distribution managers with regard to the schedulers as a whole, the survey data are considered unsuitable to allow for a meaningful statistical analysis of the association between **system ownership** and **CVRS success.**

7.2.5.2 Results in detail

Following the logic of *triangulation of measurement*, which aims to provide mutual confirmation to the same research subject by evidence from both qualitative and quantitative research methods, thus enhancing the validity of the conclusions, the following sections will focus on those implementation sub-hypotheses which are significantly supported by findings of both the survey research and the case study research. These are:

- **Sub-hypothesis** *7.2*: Diagnosis - Analysis of physical distribution;
- ***Sub-Hypothesis*** *7.4*: Planning - Defining an implementation plan;
- ***Sub-Hypothesis*** *7.5*: Action - Demonstrating top-management support;
- ***Sub-Hypothesis*** *7.9*: Action - Developing conviction, commitment and ambition; and

- ***Sub-Hypothesis 7.14***: Post-implementation - Keeping distribution data up to date.

Mixed results, that is full evidence from the case study, but only partially significant evidence from the survey, were found in relation to the sub-hypotheses:

- ***Sub-Hypothesis 7.6***: Action - Appointing a project leader; and

- ***Sub-Hypothesis 7.12***: Evaluation - Assessing how objectives have been met and adjusting the system.

Moreover, each implementation aspect will be supported by evidence of past empirical studies as appropriate.

For convenience, the results of the survey are presented in such a way that distribution sites which managed to achieve transport cost savings directly from using CVRS will be referred to as "successful systems" (SS); distribution sites which failed to do so are referred to as "unsuccessful systems" (US).

7.2.5.2.1 Diagnosis - Analysis of physical distribution

Sub-hypothesis 7.2: A highly detailed analysis of the CVRS users' distribution environment with the aim of identifying the actual information requirements of CVRS is positively associated with CVRS success.

Past research

The importance of conducting extensive analysis before developing information systems has been stressed by McKeen [1983]. In his research he reveals a positive correlation between the time and effort spent on pre-project analysis and the system's cost efficiency as well as its user satisfaction.

Current case studies and expert interviews

The distribution environment and associated requirements in CVRS can vary significantly from one organisation to another. Some typical characteristics of physical distribution in the brewing industry are illustrated below:

- Road database: Brewery-A, Brewery-C, Brewery-E, Brewery-G, Brewery-H use a remuneration bonus scheme by which their drivers are paid according to "planned" vehicle mileage. Therefore, the breweries require a CVRSS with a road database including road distances, driving speeds and associated travel times which accurately model their actual road infrastructure and driving conditions. Moreover, their CVRSS needs to allow for customers to be located in the road network with a high level of accuracy.

  CVRSSs tend to vary significantly in the level of road detail, for which a useful measure is the number of road nodes and road links held in the road database. The number of road nodes and road links of the CVRSSs available at the time of writing, varied from 20,000 to 40,000 and 30,000 to 60,000 respectively. One supplier, who is relatively new on the market, has recently upgraded his CVRSS (*Optrak*) by integrating a road database containing the road detail of the *Bartholomew* road atlas with a mapping scale of 1:250,000. The road database includes more than 120,000 road nodes and 180,000 road links. Evidence also suggests that software suppliers apply different techniques for determining locations in the road database or network thus affecting the accuracy of both route distance and associated driving time [Eibl, 1993c].

- Special transport constraints: Breweries sometimes face the constraint that certain customer deliveries can only be unloaded from a certain side of the vehicle (left-side-only, right-side only or rear-side-only deliveries). For example: a vehicle with four tonnes loading capacity at each side (left and right) may deliver goods in a long one-way street in the West End of London. Each customer receives an order of approximately one tonne. Goods are delivered from the street, as no parking space for heavy goods vehicles is available. Delivered goods are replaced with empties. For work safety reasons goods must not be loaded or unloaded facing the open street, but only facing the customers' premises. Hence, the vehicle can deliver up to a maximum of four customers within the same street. Otherwise the drivers face the inconvenience of having to lift goods over one another or to move empties. Brewery-C and Brewery-G selected a CVRSS (*Routemaster* and *DiPS*) which was tailored to fit this delivery constraint.

- Multi-depot-planning: Brewery-A, operating more than 10 depots spread throughout Britain, intends to implement a special multi-depot CVRSS. Such a system facilitates routes to be planned simultaneously at one or several central sites on behalf of other depots rather than separately at each individual depot. This would significantly reduce labour costs for vehicle schedulers. In addition, transport costs are likely to be saved, as operations can be planned and controlled more tightly and efficiently than when they are decentralised. Brewery-B and Brewery-C are also heading towards multi-depot planning. Initial steps in this direction have already been taken in that some of breweries' distribution sites operate a CVRSS on behalf of other nearby depots. However, routes are still planned individually for each depot, as opposed to simultaneously for several depots. Both companies plan to implement simultaneous multi-depot planning in the near future.

Eleven out of twelve companies reported that they conducted an in-depth analysis of their distribution environment in order to determine their actual requirements in CVRS. Brewery-M, which abandoned the use of the software, reported that it had conducted such analysis only to a very low extent. The software (*Dayload*) was selected by the central information technology (IT) department of the site's parent company. The IT department failed both to consult Brewery-M in this matter and to analyse its particular requirements prior to implementing the software. The system was virtually forced onto the site as an experiment.

Using *Dayload*, Brewery-M's daily VRS period increased from about 40 minutes during manual VRS to more than 2.5 hours. The system required about 45 minutes for automatically generating an initial route proposal. A further 60 to 90 minutes were needed to adjust the routes as appropriate using the system's interactive route editor, as the system generated unacceptable route patterns. All in all, neither management nor the vehicle schedulers were satisfied with the software, for it neither improved the routes' quality, nor reduced or even came close to the original VRS period. Instead, it disrupted the total work routine, resulting in an excessive extra work load. In fact, due to the necessary excessive manual intervention, CVRS virtually resulted in manual planning. The system's use was abandoned after a period of 4 weeks.

Summarising the facts, there is some evidence that the lack of analysis effort may have led to the selection of a CVRSS which did not fully meet Brewery-M's requirements. Also the software was not implemented adequately.

The above findings suggest that a careful analysis of a company's individual requirements of CVRS is a pre-condition for CVRS success. This ensures that the right system is acquired and implemented effectively. The analysis should not only cover technical issues but also emotional issues of the personnel affected by the software's usage. Important criteria of such an analysis are:

- the required planning speed for processing daily orders;
- whether CVRS should be conducted individually for single sites or simultaneously for multiple sites;
- the tasks to be carried out using CVRS (strategic-tactical, operational);
- the transport constraints to be considered by the CVRSS (e.g. unloading of vehicles from one side only, access restrictions, complexity of road infrastructure etc.);
- the required accuracy of allocating customers to the road network;
- the required quality of software's road database (road detail, flexibility, control, one-way streets etc.)
- the adaptability of CVRSSs to existing hardware and software systems;
- the compatibility of the CVRS software with existing work procedures;
- the acceptability/tolerance level of the CVRS software by the work force; and
- the qualification profile which the CVRS operator needs to satisfy.

Current survey

The data support *sub-hypothesis 7.2*. The results suggest a moderately significant difference in the implementation variable **analysis measures** between successful systems and unsuccessful systems. Successful systems (SS) rank higher than unsuccessful systems (US), (I-119: SS = 14.1; US = 8.7; significance level "p" = 10%; I-120: SS = 14.9; US = 8.6; significance level "p" = 10%).

The companies currently using CVRS and companies planning to use such software in the near future were asked to rank (on a *semantic differential seven-point scale*) technical features of CVRSSs in relation to their importance in the approval of the software (Table 7.14). The score of 7 represents the highest importance and the score of 1 the lowest importance. The same rating was performed regarding the objectives specified for the software's approval (Table 7.15).

Indicator (contents)	Indicator (label)	Ave-rage
High user friendliness	O-2	6.48
Accurate road network using true distances	O-7	6.35
High availability of interactive features	O-6	6.23
Quick response time (time between a user request and reply)	O-12	6.23
Highly flexible road network for adaptation to infrastructure	O-4	6.13
Overriding facilities for adding late orders to existing routes	O-3	6.04
High flexibility to adjust to new requirements, conditions etc.	O-10	6.04
High data processing speed	O-11	6.00
Reasonable investment costs	O-1	5.78
High compatibility with existing hardware and software	O-5	5.61
Convenient interface to existing software/hardware	O-13	5.52
Availability of analysis features (statistics, reports etc.)	O-9	5.22
Sophisticated route graphics	O-8	4.91

Table 7.14: Technical requirements of operational CVRS in the brewing industry

The findings suggest that breweries select CVRS technology mainly on the basis of the **user friendliness**, **road network** and **interactive features** criteria. The **investment costs** of the software and the **compatibility** with existing software and hardware systems appear to be issues of secondary consideration.

In contrast, **sophisticated route graphics** and **analysis features** (e.g. daily and weekly route statistics including drivers' working times, number of drops, mileage covered, average utilisation of vehicles, average speeds, average delivery per customer, order frequency per customer, transport volume per mile etc.) appear to play a less significant role in the software's approval.

Similar findings were derived from the author's case studies research: As far as operational CVRS is concerned, route graphics can help the inexperienced scheduler, for example, to determine the geographical position of non-allocated orders (orders which the software failed to allocate to routes) in relation to orders already allocated to routes.

Indicator (contents)	Indicator (label)	Average
Improving the ability to cope with delivery constraints	O-23	6.70
Enhancing the customer service level	O-25	6.48
Reducing vehicle mileage	O-14	6.41
Increasing the route planning speed	O-19	6.36
Avoiding the occurrence of human errors	O-21	6.17
Increasing the vehicle utilisation by weight/volume	O-15	6.14
Reducing costs for office staff	O-17	5.90
Facilitating the route planning procedure	O-18	5.76
Improving the control over the transport operation	O-28	5.74
Increasing the vehicle utilisation by time	O-16	5.64
Reducing the amount of paperwork to be processed	O-20	5.57
Reducing the duplication of work effort/data entry	O-24	5.57
Increasing the availability of transport information	O-22	5.55
Improving the transparency of costs involved in transport	O-29	5.50
Improving the availability and statistical analysis of distribution data	O-30	5.43
Decreasing the company's dependence on the vehicle scheduler	O-26	5.26
Reducing the time period required for learning CVRS	O-27	5.09

Table 7.15: Objectives of using operational CVRS in the brewing industry

Enhanced **customer service** and more effective **coping with delivery constraints** are the main benefits breweries expect from using CVRS. Of relatively high importance is the software's ability to provide tangible or "hard" benefits in terms of **reducing vehicle mileage** and **increasing the vehicle utilisation** by weight or volume which ultimately may result in a **reduction of the vehicle fleet**. Moreover, breweries aim to **reduce the VRS period** and thus **cut costs for office staff**. Avoiding the occurrence of **human errors** such as the omission of sales order notes, bad handwriting etc. is also one of the key objectives.

The **availability of transport information** and **improved transparency of costs** involved in transport are given a lower priority. Also less important is the **availability of features for statistical analysis**. This confirms the findings of Wright and Cross [1985] who suggest that companies appear to be less concerned with control and fail to see management information as a priority.

7.2.5.2.2 Planning - Defining an implementation plan

Sub-hypothesis 7.4: Thorough planning and organisation of the CVRSS's implementation, ensuring that all required human and technical resources are available at the right place and right point of time, are positively associated with CVRS success.

Past research

Ginzberg [1981a, p. 54] highlights the definition and planning of the implementation process as a key factor: "Detailed consideration of organisational needs, project impacts, training requirements, and evaluation criteria, as well as care in specifying the roles of project team members, are all part of this factor". Meador et al [1984, p. 127] suggest that project planning and evaluation are "particularly important and difficult, because they require the DSS developer to assess user's needs and how they are being (or could be) met by a DSS, and what the DSS should look like to serve those needs" .

Current case studies and expert interviews

The CVRS users that were analysed reported an average CVRS implementation period of 16 full-time man weeks. This period comprises all activities from data collection, through data validation to the use of the software in "live" operations. However, some users have experienced implementation periods as short as 6 weeks while others required more than 25 weeks. Critical factors which determine the actual implementation period are:

- the size and complexity of the users' transport operations;
- the extent to which distribution data are readily available;
- the extent of software customisation required,
- the complexity of the software used; and
- **perhaps most importantly**, the <u>quality</u> of the implementation's planning and organisation.

Large organisations with several depots commonly found that the implementation period decreased significantly with experience gained from installing initial copies of the software. Thus, Brewery-B and Brewery-C managed to reduce the total implementation period per depot from initially around 16 full time man-weeks to an average of less than 7 full-time man-weeks for most of the subsequent installations.

With regard to the lengthy and complex process of implementing CVRS software, all the organisations interviewed stressed the importance of planning and organisation. Ideally, each stage of the implementation needs to be strictly defined in terms of its work tasks and individuals' responsibilities as well as the estimated work times required. The progress made needs to be evaluated at regular intervals and the plan has to be adjusted as appropriate.

Some critical issues which usually require time and therefore need careful planning are:

- collecting and entering data on the users' distribution environment including the depot(s), vehicles, drivers, products, customers and road network[6];
- adapting the software's road database to individual requirements; that is, manually adding new roads links or suspending existing road links which are considered unsuitable for use by delivery vehicles;
- validating and correcting data, in particular customers' postcodes, time windows and other access restriction, until they are completely free of error;
- fine tuning the software's planning parameters, for example inter-customer travel times for customers allocated to the same road node, until the software produces acceptable routes;
- providing specialised user training on the software;
- building up the users' confidence in the system;
- adjusting distribution policies relating to, for example, the drivers' pay scheme and unfavourable union rules regarding the loading of vehicles below the legally allowed capacity or restrictions on the daily number of trips per route (per vehicle);
- adjusting work procedures in physical distribution and related areas;
- specifying responsibilities for new and continuing working tasks in distribution and related areas; and
- creating software interfaces.

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[6] Examples of the data required are presented in Appendix 4, p. A-35.

It is important to take advantage of the momentum of individuals' motivation developed at the project outset. Any unnecessary delays tend to endanger the implementation's success. The longer the project lasts, the more difficult it is for management to keep up individuals' enthusiasm and commitment to the project. Evidence from interviews with software suppliers suggests that one frequent reason for the abandonment of CVRSSs is the loss of individuals' interest in the project, which is often caused by a lack of timely planning effort.

Current survey

The survey data strongly support *sub-hypothesis 7.4*. The results suggest a highly significant difference in the implementation variable **implementation's planning and organisation** between successful and unsuccessful systems. Successful systems rank higher than unsuccessful systems (I-121: SS = 17.7; US = 7.4; significance level "p" = 1%).

7.2.5.2.3 Action - Top-management support

***Sub-hypothesis** 7.5*: Top-management support for the CVRS project is positively associated with CVRS success.

Past research

According to Schein [1961, p. 66] the presence of models or model attitudes and behaviour is a crucial factor in any planned change. Through the process of identification and/or internalisation individuals develop new attitudes and associated new patterns of behaviour. More recent research on the implementation of IT also emphasises the importance of management leadership and top-management support [Lucas, 1974; Schulz and Slevin, 1975; Meador et al, 1984; Sanders and Courtney, 1985; Lucas et al, 1990].

Current case studies and expert interviews

Following Schulz's and Slevin's [1975] view of the importance of user involvement, the normative generalisations about top-management support need to be made contingent on factors such as the organisational, social, and task contexts of the situation.

The issue of top-management support appears to be particularly critical in large organisations, where the CVRSSs' users are geographically separated from the CVRS decision makers. A lack of top-management support in combination with other unfavourable factors such as negative attitudes towards the CVRSSs among the operational personnel on site can hinder the implementation or, at the most extreme, cause individuals to completely reject the software.

Such cases have been experienced at Brewery-C, where the responsibilities of physical distribution are held by several regional distribution directors. Because one regional director did not approve of the use of CVRS, the distribution sites under his control failed to implement the software. Despite strong efforts made by the brewery's head office to push through the change towards CVRS, this situation did not change, until the regional director was replaced by a member of management who was in favour of CVRS.

Brewery-A, Brewery-B and Brewery-G reported similar cases which all stress the importance of top-management support which seems to be a necessity for allowing individuals to develop positive system attitudes and implementation behaviour, in that it provides a model of how to respond.

In contrast, Brewery-I, which is a regional division of a major brewing group, had rather favourable experiences. The regional distribution director of Brewery-I strongly supported the use of strategic-tactical CVRS which was implemented at the region's management service department. As a result, the operations managers of two other regional divisions within the same brewing group became aware of and interested in the technology. Eventually, both managers decided to implement the software.

Current survey

The survey data provide moderate support for *sub-hypothesis 7.5*. The results suggest a moderately significant difference in the implementation variable **top-management support** between successful systems and unsuccessful systems. Successful systems rank higher than unsuccessful systems (I-123: SS = 17.9; US = 10.5; significance level "p" = 10%).

7.2.5.2.4 Action - Appointing a project leader

Sub-hypothesis 7.6: The availability of centralised responsibility through a project leader during the software's implementation is positively associated with CVRS success. This effect is greatest if the project leader possesses technical competence and decision-making authority given by his/her status at a high level in the organisation.

Past research

Edström [1977] has investigated the success of MIS projects in 16 companies. His results reveal a correlation between project success and the influence of the system development manager and project leader during the system installation.

Similar findings have been revealed by Welsch's study [1981, p. 208] of 45 DSSs. Welsch defines the project leader as an *information transfer specialist*. "The role of the information transfer specialist is to achieve integration or unity of effort between the DSS and the decision makers using the system". The study provides evidence that the function of the information transfer specialist is significantly correlated with the perceived DSS implementation success.

Maisch [1979] finds a positive correlation between favourable user behaviour and positive feelings about the quality of the system staff.

Ein-Dor and Segev [1981, p. 77] suggest that "Steering committees composed of high-level corporate officers enhance the likelihood of MIS and MIS project success". They conclude: "Steering committees have been advocated both as a way of showing management support and as a method of attaining user involvement".

Also Lucas [1976] highlights the benefits of centralised responsibilities in the implementation of projects. He proposes the establishment of *steering committees* which plan, organise, guide and supervise the implementation of information systems.

Similarly, the empirical studies of Zielinski [1984] as well as Eastburn and Christensen [1986] illustrate how the formation of steering committees can aid the implementation of CVRSSs.

The most extreme approach was taken in the research of Eastburn and Christensen. Here the project team was made fully responsible for getting the CVRSS working rather than simply providing assistance to operational management.

Current case studies and expert interviews

The implementation of CVRSSs is a lengthy and complex procedure, which affects existing software systems and individuals not only in the transport function and other operational areas of physical distribution, but also in related business functions, for example marketing and finance. Given the cross-sectional nature of the VRS function the CVRS users investigated generally felt that the CVRS project had benefited from the availability of centralised responsibility during and after the software's implementation.

In smaller or strongly decentralised organisations such as Brewery-D, Brewery-E, Brewery-F, Brewery-H, and Brewery-K, where decisions to invest in IT are made by local transport or distribution functions, the centralised responsibility was allocated to one or several appointed members of management, these usually being the local transport or distribution managers. In larger organisations, such as Brewery-A, Brewery-B and Brewery-C, where decisions on IT in transport are made by the head office, centralised CVRS responsibilities were carried out by *system steering groups.* These were composed of experts chosen predominantly from central management service functions in the area of data processing, logistics, and distribution.

The steering groups in Brewery-A and Brewery-C dealt with both strategic and operational issues of the software's implementation. Brewery-B, however, decided on a more differentiated approach by allocating the implementation tasks to a **strategic** steering group and an **operational** steering group. The strategic steering group was located at the head office where it defined the project's objectives and long-term plan. Moreover, it ensured that all necessary financial and material resources were made available at the right place and the right time. Finally, the strategic steering group took a "stepping back view" to oversee the project's development and ensure that the set objectives were met. In contrast, the operational steering group worked at the individual distribution sites in co-operation with the sites' operational key-personnel. Here it aimed to put the strategic plan into practice and thus functioned as the interface between the strategic steering group and the individuals at the local distribution sites. To carry out this task effectively, the two steering groups met at regular intervals.

Particularly in some of the larger organisations, special attention was paid to nominating a CVRS project leader with full decision-making authority and a fair amount of specialised computer knowledge. This proved beneficial for dealing with technical problems and being able to mediate in the solution of social conflicts occurring within and between business functions, thus facilitating the overall implementation process.

A lack of continuing centralised responsibilities throughout all stages of the software's implementation was observed at the German contract distributor Haulier-Q. The project was initially led by the company's distribution systems manager. The implementation was extremely time consuming. Several months were spent on setting up the software, in particular the allocation of customers to the software's road database. A number of technical problems occurred, which were dealt with by the software's supplier. Before the software was fully operational, the project leader moved on in the company. As nobody within the organisation had the ability or interest needed to continue the software's implementation, the system was abandoned. Interviews between the author of the current research and the software's supplier revealed that the technical problems which occurred at Haulier-Q could have been resolved. However, the software house was unable to continue negotiations due to the absence of personnel responsible for the project.

A similar case was reported by a case study conducted by Waters [1986] about the implementation of computer-based algorithms to re-schedule production and improve distribution in the newspaper industry. The project's implementation was hindered by an apparent lack of management control. Also, the dispatch department and the drivers, as well as their trade unions, were reluctant to provide the necessary implementation support, with important distribution data not being collected or analysed. The friction which occurred between different parts of the organisation often caused delays. The project eventually collapsed when the marketing manager, who had initiated and supported the project, left the company. The new marketing manager did not consider it appropriate to resume the work.

Current survey

The survey data provide mixed results to support *sub-hypothesis 7.6*. The results suggest a difference in the implementation variable **availability of centralised responsibilities** between successful systems and unsuccessful. Successful systems rank higher than unsuccessful systems. However, the association is significant only for the variable relating to the **project leader's possession of decision-making authority** (I-125: SS = 12.6; US = 6.5; significance level "p" = 5%).

The survey findings suggest that the availability of centralised authority or a project leader is likely to play a significant role in the implementation of CVRSSs. Two thirds of all implementations were guided by a project leader. The actual extent of the project leader's involvement may vary from one site to another, depending on individual needs and on the complexity of the operations. Hence, the extent of leadership may not be a relevant factor or predictor for the system's success. However, an important ingredient seems to be that the project leader has decision-making authority given to him by his rather high position in the organisation's hierarchy. Technical competence is certainly a useful characteristic; however, it may not be crucial for implementing successful CVRSSs. This may be explained by the fact that the technical set-up of software, hardware and interfaces is usually supported by the CVRS suppliers themselves and/or by specialised staff from the system users' IT department.

7.2.5.2.5 Action - Developing conviction, commitment and ambition

> ***Sub-hypothesis 7.9***: Individuals' convictions about the success of and commitment to the CVRS project are positively associated with CVRS success.

Past research

Ginzberg [1981a, p. 54] points out the relative importance of "commitment to the project" as a central issue to successful MIS implementation. He suggests that this commitment must be developed by both users and management, "as this increases the odds that they will take appropriate actions at each project stage - from pre-design through post installation - to assure the project's success".

Burnes [1992, p. 266] emphasises the importance of the commitment and support of all concerned, especially those who are most closely affected. It enables notoriously difficult and unexpected problems which occur during the change process to be overcome and to "develop and maintain the momentum necessary to ensure the project is successful". Therefore, Burnes emphasises the concept of "commitment planning" which "involves identifying key people and groups whose commitment is needed for change to occur and deciding how to gain their support".

Current case studies and expert interviews

In eleven out of twelve organisations individuals' convictions about CVRS success and commitment to the projects were generally high. Managers' ratings were highest, followed by the schedulers' ratings and, not surprisingly, ratings were lowest for drivers. Only Brewery-M, which abandoned the software's use after only a few weeks of usage, reported consistently low ratings for all individuals affected by the implementation, including the transport manager.

The attitude and behaviour of the distribution managers provide, as with top-management support, a model for the operational personnel affected by the software. Such personnel are predominantly the vehicle schedulers and the drivers, but also staff in related business areas such as sales/marketing and inventory/warehousing. Brewery-C reported two cases where the distribution managers rejected the software. The managers and, similarly, the site's schedulers and drivers, vehemently claimed that the software was inefficient and non-operational at their particular sites. The company's centrally organised CVRS steering group investigated the situation and was able to demonstrate the software's effectiveness at both sites. However, the initial problems recurred, with the software eventually being abandoned once again. This situation did not change until the sites' managers were replaced by personnel with favourable CVRS attitudes and a willingness to force through the software's full implementation. Similar cases were reported by other large organisations with several distribution sites, for example Brewery-A and Brewery-B.

The schedulers and drivers are most affected by changes induced by the implementation of CVRSSs. The schedulers normally carry out the major work load of the implementation. Consequently, the schedulers' convictions about the success of and commitment to the project tend to be of primary importance. Evidence from the case studies suggests that it may be sufficient to successfully implement a CVRSS with the schedulers as the only driving force, provided they receive the necessary back-up support from the distribution/transport managers. However, if the drivers are equally convinced of the software's success and support the project, this tends to enormously facilitate the system's installation and subsequently leads to higher savings.

Current survey

The survey data provide strong support for *sub-hypothesis 7.9*. The results suggest a highly to moderately significant difference in the implementation variables relating to the **managers', schedulers' and drivers' convictions about the CVRS success** between successful systems and unsuccessful systems[7]. Successful systems rank higher than unsuccessful systems (I-132, managers: SS = 18.2; US = 9.1; significance level "p" = 5%), (I-133, schedulers: SS = 16.1; US = 7.0; significance level "p" = 5%), (I-133, drivers: SS = 17.4; US = 10.4; significance level "p" = 10%).

Similarly, the results suggest a highly to moderately significant difference in the implementation variables relating to the **managers', schedulers' and drivers' commitment to the CVRS project** between successful systems and unsuccessful systems. Successful systems rank higher than unsuccessful systems (I-134, managers: SS = 18.1; US = 9.8; significance level "p" = 5%), (I-135, schedulers: SS = 16.3; US = 6.2; significance level "p" = 1%), (I-137, drivers: SS = 18.3; US = 8.6; significance level "p" = 5%).

7.2.5.2.6 Evaluation - Assessing how objectives have been met and adjusting the system

> ***Sub-hypothesis 7.12***: The effort spent on assessing how far initially-set objectives have been met and, in the case of deviations, adjusting the system accordingly, is associated with CVRS success.

Past research

Kolb and Frohman [1971, p. 61] consider the evaluation phase as an integrated part of the process of change. The authors suggest the use of "objective evaluation indices that cannot be manipulated".

Current case studies and expert interviews

The objectives of using CVRSSs are usually defined by the personnel who decide on the software's implementation. In smaller organisations such as Brewery-D, Brewery-H, Brewery-J, Brewery-K, Brewery-L, with only one or few distribution sites, these personnel are usually the local transport or distribution manager. Here the evaluation and adjustment of objectives tends to be less of a problem, as the projects' initiators have permanent control over the software's implementation and subsequent use.

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[7] The results concerning the drivers' and, equally so, the schedulers' convictions about CVRS success (indicated on their behalf by the managers) are considered as indications only as opposed to firm evidence. See Section 1.4.1.2, pp. 21-22.

The objective evaluation task tends to be more critical in large organisations with multiple distribution sites, like Brewery-A, Brewery-B and Brewery-C. Here the implementation decisions have been made by centralised functions which do not have permanent control over the use of the software at each site. Brewery-C has reported on distribution sites, where the CVRSSs were used simply as an automation of manual VRS as performed by the sites prior to the software's implementation. The sites' local management failed to ensure that the software was used adequately. This problem was most critical at sites where the software had been implemented against the will of the local managers and staff. Not surprisingly, these sites made little effort to ensure that the performance of the CVRSS was assessed with respect to the initially-set objectives, let alone to take corrective measures as appropriate. Also, the sites generally failed to report problems or insufficiencies in the software's performance to the centralised logistics department which had implemented the software.

Current survey

The survey data provide mixed results to support *sub-hypothesis 7.12*. The results suggest a difference in the implementation variables **objective evaluation** and **objective adjustment** between successful systems and unsuccessful systems. Successful systems rank higher than unsuccessful systems. Nevertheless, the difference is moderately significant only for **objective evaluation**, which measures the extent to which the actual progress made was compared with the initially-set objectives (I-145: SS = 16.9; US = 9.8; significance level "p" = 10%).

7.2.5.2.7 Post-implementation - Keeping CVRS parameters up to date

Sub-hypothesis 7.14: Constantly adjusting the distribution data in accordance with changes in the distribution environment is positively associated with CVRS success.

Current case studies and expert interviews

Since route planning problems are dynamic, distribution data are exposed to constant changes. Changes can affect the customer base or distribution parameters such as opening times and delivery frequencies, vehicle availability, drivers' shift times etc. A particularly critical issue is that of changes to the road network, which may be caused by road closures, new road developments, road repair works or bad weather conditions.

Therefore, like correct data collection, frequent data up-dates are a *sine qua non* for effective CVRS. Evidence from the case studies as well as expert interviews suggests that this post-implementation aspect is often neglected. Again, this issue tends to be most critical in large organisations, where the software's purchase and implementation is supported by personnel from central service functions. As these are not permanently available at the local sites operating the software, they are often not aware when system updates become necessary.

Of great importance in this context is the quality of the on-going support provided by the software's suppliers. Updates to the road network, for example inserting newly built roads or deleting certain roads inaccessible by HGVs, can be carried out manually as required. Nevertheless, this procedure tends to lead to inaccuracies which add up in the course of time and may thus affect the planning results. Therefore, at certain intervals the road network information should be updated as a whole, using accurate data provided by the supplier. However, such complete updates must not overwrite the previously made manual alterations to the road network, for example, cancelled roads or specified road speeds.

Current survey

The data provide strong support for *sub-hypothesis 7.14*. The results suggest a highly significant difference in the implementation variable **keeping distribution data up to date** between successful systems and unsuccessful systems. Successful systems rank higher than unsuccessful systems (I-148: SS = 21.3; US = 9.7; significance level "p" = 1%).

7.3 Variables associated with organisational efficiency

7.3.1 Presentation of variables

Quality of CVRSSs: Lucas [1975] provides evidence for a positive association between system quality and level of system usage by which he operationalises system success.

A research project "Tourenplanung"[8] organised by the German transport society **Gesellschaft für Verkehrsbetriebswirtschaft und Logistik** (**GVB**) aimed at testing the

[8] Meaning: VRS.

efficiency of CVRSSs using empirical data collected from different fleet operators[9]. The research provides statistical evidence that the level of transport cost savings is influenced by the type of CVRSS used. The CVRSSs investigated were found to differ most with regard to their road database. This suggests that the quality of the software's road database is a key criterion of the quality of CVRSSs (subsequently referred to as "**CVRS system quality**").

Similar findings have been obtained from the current case study and expert interview research, suggesting that **CVRS system quality** is positively associated with **organisational efficiency** or transport cost savings. Also, the quality of the road database of CVRSSs appears to play a major role in the software's overall performance. However, these conclusions are based on qualitative evidence only and no quantitative or statistical evidence is available to support this.

Developing a valid measure for **CVRS system quality** is difficult, because the quality is relative to the specific operating environment in which the software performs. This problem will be demonstrated in subsequent Section 7.3.3 by the example of three case studies[10]. Due to the lack of a valid measure of **CVRS system quality,** the latter was not evaluated with quantitative evidence from the survey. However, the case studies conducted within this research supplies good qualitative evidence for the impact of **CVRS system quality** on **organisational efficiency** in terms of transport cost savings.

CVRS operator's performance: Schedulers with a high ability to operate their CVRSS are expected to generate cost-effective routes which increase **organisational efficiency**.

Drivers' performance: The higher the ability of the drivers to meet the working standards indicated by the computer-generated routes in terms of delivery sequence and delivery times, the higher the impact on **organisational efficiency** is expected to be.

It is expected that the above variables have a *combined impact* on **organisational efficiency**. Hence, **organisational efficiency** (dependent variable) may be highest if all three independent variables score highly. This is illustrated by the following example:

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[9] Address of GVB: GVB Zentralstelle, Börsenplatz 1, 60131 Frankfurt; for further detail on the project see Bargl, 1994, 1992; Klaus, 1990.

[10] See Section 7.3.3, p. 224f.

A highly sophisticated CVRSS with effective algorithms, high user friendliness and flexibility etc. may perform extremely well, thus fully meeting a company's requirements. The **CVRS operators' performance** is high; that is, the schedulers are capable of using the software at its full potential and therefore achieves good planning results. However, the drivers are dissatisfied with the changes in their work routine and flexibility induced by the software. In protest at the new situation, the drivers perform poorly by not adhering to the delivery sequence and times proposed by the CVRSS. Consequently, **organisational efficiency** may only increase marginally, remain unchanged or, at the most extreme, decline and this despite the high **CVRS system quality** and high **CVRS operators' performance** .

While the above example may illustrate a rather extreme scenario, in practice the level of **organisational efficiency** will vary according to the combination of the independent variables. Ideally, the combined or interactive effect of variables may be measured by the use of multivariate statistics such as *multiple regression*, *MANOVA* and *discriminant function analysis*. However, because there is evidence that the data for some variables used in the current research do not comply with the *normality* assumption[11], the data analysis is based exclusively on univariate and bivariate non-parametric statistics.

The above variables form the following hypotheses:

Hypotheses 8a - 8c: Organisational efficiency of CVRS users is positively associated with:

- CVRS system quality (*hypothesis 8a*);
- CVRS operators' performance (*hypothesis 8b*); and
- Drivers' performance (*hypothesis 8c*).

7.3.2 Measurement of variables

Operationalisation of concepts

The operationalisation of the **organisational efficiency** concept has been shown previously in Table 7.1[12]. As outlined above[13], the **CVRS system quality** concept has not been operationalised for use in the survey.

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[11] See Section 5.2.2, pp. 131-132.

[12] See Table 7.1, p. 184.

[13] See Section 7.3.1, pp. 218-219.

The following Tables 7.16 and 7.17 show the operationalisation of the **CVRS operators' performance** concept and **drivers' performance** concept respectively

Concept	Dimension	Indicator (contents)	Indicator (label)
CVRS operators' performance	(not applicable)	Understanding of the CVRSS	J-154
		Ability to use all relevant functions of the CVRSS	J-155
		Ability to use the CVRSS at full potential	J-156
		Scope for improving ability to operate the CVRSS	J-157i

Table 7.16: Operationalisation of the *CVRS operators' performance* concept

Concept	Dimension	Indicator (contents)	Indicator (label)
Drivers' performance	Drivers' performance A	Ambition of drivers to meet CVRS working standards	K-177d
	+ Drivers' performance B	Actual meeting of CVRS working standards	K-178d

Table 7.17: Operationalisation of the *drivers' performance* concept

The dimension **drivers' performance B** (indicator: K-178d) is marked "+". This is because, in relation to **organisational efficiency,** the drivers' actual meeting of work standards such as delivery sequence, vehicle mileage and driving time is considered to be a better measure of the overall **drivers' performance** than the ambition to do so.

Selection of scales and formation of indices

The **CVRS operators' performance** and **drivers' performance** dimensions are measured by indicators based on a *semantic differential seven-point scale.* Again, the managers and the schedulers responded on behalf of the drivers as a whole. The rankings given to each indicator are averaged.

Organisational efficiency is measured on a nominal scale indicating whether or not CVRS has led to transport cost savings.

The three indicators J-154, J-155 and J-156 of **CVRS operators' performance** correlate highly at the 1% significance level. Despite the fact that the fourth indicator J-157i was formulated in such a way that it measures the same concept as the other three, it correlates only moderately. The same conclusion is derived from *factor analysis* which shows that J-157i loads only 0.54 while the other indicators load 0.90 and higher (see following Table 7.18). The findings give good reason to assume that this particular indicator may have been misinterpreted by the respondents. For this reason, the indicator will not be considered in further analysis. The other three indicators are averaged to form a **CVRS operators' performance** index.

Reliability and validity of measurement

The above **CVRS operators' performance index** is considered to be a reliable and valid measure as substantiated below:

R*eliability* or *internal consistency* of the index is emphasised by a high *Cronbach Alpha coefficient* of 0.91 which is well above the minimum level of 0.8.

Construct validity of the index measure is emphasised by *factor loadings* substantially higher than the minimum score of 0.6. Further support is given by the overall high correlation (*total score correlation*) between individual indicators and the sum of the other indicators (Table 7.18).

Indicator (Content)	Factor loading	Total score correlation	p %
Understanding of CVRSS	0.91	0.66	1
Ability to use all relevant functions of CVRSS	0.94	0.68	1
Ability to use CVRS at full potential	0.90	0.61	1
Scope for improving CVRS[1)]	0.54	*	*

*As suggest by its low pairwise correlation (not shown in this table) with each of the other indicators and its low factor loading (0.54), this indicator does not enter the *CVRS operator's performance* index. For this reason no *total score correlation* (correlation between this indicator and the sum of the other three indicators) was calculated for this indicator.

Table 7.18: Factor analysis and total score correlation for testing construct validity of the *CVRS operators' performance* index

Data analysis

Hypothesis 8a is tested with data provided by the case studies on a non-statistical basis. The *hypotheses 8b* and *8c* are tested with survey data using the *Kruskal-Wallis procedure*.

7.3.3 Results

Table 7.19[14] shows the results of the *Kruskal-Wallis test* performed on *hypotheses 8b - 8c*.

Independent variable	Dependent variable		
	Organisational efficiency		
Concept/ Dimension	Transport cost savings	No transport cost savings	Sign. level (p in %)
	Rank	Rank	
CVRS operators' performance	24.7	26.0	ns
Drivers' performance A	19.9	11.6	**10**
+ Drivers' performance B	20.0	10.8	**5**

Table 7.19: Kruskal-Wallis test for *hypotheses 8b - 8c*

The results are discussed below:

CVRS operators' performance:

The survey data do not support *hypothesis 8b* suggesting that **CVRS operators' performance** is associated with **organisational efficiency**. This may be explained by the interactive or combined effect of the independent variables as outlined above. An alternative explanation may be the fact that the data do not include all CVRS operators of the sites participating in the survey. Therefore, the impact of the **CVRS operators' performance** on **organisational efficiency** may not have been assessed to the full extent.

However, some qualitative evidence for the association is provided by the case studies. At Brewery-D operational CVRS is carried out by two schedulers, here referred to as *scheduler A* and *scheduler B*. Management reported that *scheduler A* handled the software significantly more effectively than *scheduler B*. As a result, the planning results of scheduler A were between 5% and 10% superior to those of *scheduler B*. The importance of the schedulers' CVRS operating capabilities for achieving good planning results was generally confirmed by interviews conducted with both managers of the company case studies and the software suppliers.

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[14] For further detail see Table A2-8 (Appendix 2), p. A-31.

Drivers' performance:

The data support *hypothesis 8c* suggesting that **drivers' performance** is associated with **organisational efficiency**. The results suggest a significant to moderately significant difference in **drivers' performance A** and **drivers' performance B** between sites which achieved transport cost savings and those which failed to do so (**organisational efficiency**). Both dimensions rank higher at sites which achieved transport cost savings than at sites without transport cost savings. The highest significance level is found with respect to **drivers' performance B,** marked with a "+".

These findings are supported by the qualitative evidence of the case studies, suggesting that the drivers' adhering to the computer-generated route plans is vital to system success. Instances have been reported about distribution sites where CVRS failed to improve transport productivity or, at the most extreme, reduced transport productivity due to the drivers' disruptive work behaviour in protest to the software. Such cases were most severe at sites where both management and staff had rather negative initial attitudes towards the software.

Table 7.20 summarises the average scores of the **drivers' performance** dimensions differentiated by sites which managed to achieve transport costs saving and those which failed to do so[15].

Dimension	Sites which achieved transport costs savings	Sites which failed to achieve transport cost savings	Max. score obtainable
	Mean score	Mean score	
Drivers' performance A	4.6	3.3	7
+ Drivers' performance B	5.5	4.0	7

Table 7.20: Mean scores of *drivers' performance* dimensions

CVRSS quality:

Previous sections have raised the problems involved in developing a valid measure of **CVRS system quality**. A general problem of **CVRS system quality** is that it is relative to individual requirements in road transport. This assumption will be supported by the following example of three breweries investigated within the case study research. While

[15] For further detail see Table A2-9 (Appendix 2), p. A-32.

this example highlights the problem of finding accurate measures for **CVRS system quality**, it also provides some indications for the impact of this variable on **organisational efficiency**.

CVRS experiences in Brewery-G, -H, and -K: The use of the CVRSS *Dayload* at Brewery-K reduced the daily VRS period, vehicle mileage and size of the vehicle fleet. In contrast, the same CVRSS facing considerably more complex transport problems at Brewery-G and Brewery-H failed to save vehicle mileage and reduce the fleet size, as shown in Table 7.21.

Distribution site	**Complexity of transport problems**					**Organisational efficiency**		
	Daily orders	**Daily orders/ trip**	**Vehicles**	**Tonnes p. a. (1000)**	**Complexity of road infrastructure**	**Vehicles in %**	**Reduction in mileage**	**Reduction in VRS period in %**
Brewery -G	280	7 - 9	35	200	High complexity (London)	0	no	yes*
Brewery -H	420	10	42	120	Medium complexity (South Yorkshire)	0	no	50
Brewery -K	70	5	15	23	Medium to low complexity (South/West Wales)	- 13	yes	50

* A reduction in VRS period was achieved, but the extent was not quantifiable.

Table 7.21: Impact of CVRSS *Dayload* on *organisational efficiency*

Brewery-G and Brewery-H blamed the software's failure to reduce vehicle mileage and the fleet size on the quality of the software's planning algorithms. In order to achieve a satisfactorily short daily VRS period and avoid the generation of "unacceptable" or "odd" route structures, the breweries categorised their customers by zones. Hence, routes were planned in a semi-fixed manner by zones or customer groups, as opposed to the fully flexible approach, where orders are allocated to routes in one single run for the total delivery area.

By using the software's zoning facility, the breweries overall managed to achieve acceptable VRS periods. However, the software failed to produce cost-effective routes. This was predominantly blamed on the software's lack of flexibility in the allocation of orders to routes. In fact, the software was unable to effectively transfer orders between zones. This resulted in excessive numbers of non-allocated orders. Consequently, in an effort to achieve satisfactory planning results, both breweries required excessive daily manual intervention in order to re-adjust routes within and between zones.

At Brewery-G the *Dayload* system led to a further major problem caused by its road database. It was unable to effectively model the complex road infrastructure of Brewery-G's distribution area covering the London region. For instance, routes were planned across estuaries and the software was unable to cope effectively with constraints such as one-way streets, narrow lanes or streets with low bridges. Consequently, Brewery-G regularly needed to manually modify the road database by adding new road sections or deleting existing ones as appropriate.

At Brewery-K, in contrast, the above problems did not occur or were less significant. Because of the small number of daily orders, the software produced results which were satisfactory overall. The VRS period was acceptable and manual intervention was much less of an issue. Also, the software was able to sufficiently model the road infrastructure of Brewery-K's delivery area in South and West Wales, which is significantly less complex than in the case of Brewery-G.

It is suggested, therefore, that the evaluation of **CVRS system quality** requires relative measures. Ideally, such a measure should divide transport problems according to their level of complexity, for example high, medium and low complexity. Classification criteria may be the road infrastructure (percentage of one-way streets, density of road network in terms of road nodes and links etc.), number and types of delivery constraints (left/right/tail deliveries, time windows etc.) and number of daily orders. For practical reasons the current research has been unable to develop or operationalise any such *relative* measure of **CVRS system quality**. Therefore, the association between **CVRS system quality** and **organisational efficiency** has not been tested in a structured form via the survey. However, some support for the association is provided from the case studies.

It should be noted that if such a *relative* measure of **CVRS system quality** were available, it would be of limited use for testing with the current survey data. This is because the depots participating in the research use different versions of particular packages, with some being regularly updated and others not. Moreover, the packages used have different levels of customisation.

Some support for the assumed positive relationship between **CVRS system quality** and **organisational efficiency** has been presented by the above case study evidence. As far as Brewery-G and Brewery-H described in Table 7.21 are concerned, these considered the CVRSS *Dayload* to be inadequate for their actual requirements. Eventually, both breweries decided to replace the software by a new CVRSS (*DiPS* and *Paragon2* respectively). Without having conducted a detailed comparative analysis of all CVRSS available on the market, the author of this research rates the *Dayload* system as one of the least sophisticated.

Kruskal-Wallis test: A purely subjective but, nevertheless, interesting observation has been made from a *Kruskal-Wallis test* of the relationship between **organisational efficiency** (transport cost savings: yes/no) and the author's personal rating of **CVRS system quality**. The packages used in an operational role by the depots participating in this research have been divided into two groups. The groups are set up in such a way that they are differentiated by **CVRS system quality**:

- The first group includes the *Dayload* system representing a package with low relative **CVRS system quality**.

- The second group includes all remaining systems (*Routemaster*, *Visit* and *DiPS*) representing packages with high relative **CVRS system quality**.

The *Kruskal-Wallis test* suggests a significant difference between the two groups with the second group ranking higher than the first group (average rank of first and second group: 12.1 and 20.6 respectively; "p" = 5%). In other words, the sites using the *Dayload* system differ significantly with regard to their ability to reduce transport costs compared to sites using the *Routemaster*, *Visit* or *DiPS* systems.

Comparative study of CVRSSs in Brewery-C: Further elaboration of the impact of **CVRS system quality** on **organisational efficiency,** is provided by the centralised logistics department of Brewery-C. This brewery has been using the *Visit* system in an operational role for several years during which it constantly observed the developments taking place in the British CVRS market. The brewery recently conducted a comparative study between *Visit* and two relatively new systems (*Roadshow* and *Optrak*) on the British market. The analysis was conducted with the aim of identifying whether or not to replace *Visit* by either of the two other packages tested.

The systems have been tested for use in an operational role. It should be noted that the test results relate to the brewery's specific requirements and the complexity of its transport problems. Hence, the results are company-specific and may not necessarily apply to organisations other than Brewery-C.

The packages investigated have been reported to vary significantly in the following key areas:

- Ease of implementation and maintenance;
- User interface;
- Control over the route generation process;
- Planning speed or reduction of VRS period;
- Quality of the road database; and
- Quality of the planning results in terms of vehicle mileage and utilisation as well as coping with delivery constraints.

The following presentation of the results in further detail is preceded by some general background information about the packages involved. The information provided is by no means comprehensive and is merely intended to facilitate the comprehension of the results:

Visit: The *Visit* system is supplied as a readily-available, special industry-specific "brewery version". The software is fully interactive and includes a graphical colour display of routes as well as the underlying road network. A special feature is the availability of a *strategy programming language* used for the generation of *strategy files*. These are comparable to sub-routines which control the general planning procedure of the system's basic algorithms to suit the user's special requirements, order priorities and delivery constraints. The strategy programming language can be used in connection with a set of general control parameters (e.g. geographical zones, number of trips per vehicle or vehicle group) and the option to define individual customers or groups of customers as appropriate (e.g. AM/PM orders, high priority orders, three men orders, left side/right side/tail deliveries etc.).

Strategy files are user-defined and therefore adjustable to individual requirements. The user can develop his/her own library of strategy files which may vary on a daily basis. Strategy files can be used individually or, for more complex tasks, in combined form. For instance (see Figure 7.2), a certain strategy might cause *Visit* to plan all priority orders first, so as to make sure they are planned into a particular day's deliveries. A subsequent strategy run might induce *Visit* to plan orders of customers with restricted access or within a certain area. A further strategy might force *Visit* to plan orders which require three men vehicles to be carried out. Finally, a general strategy may give *Visit* a free hand to plan all remaining orders.

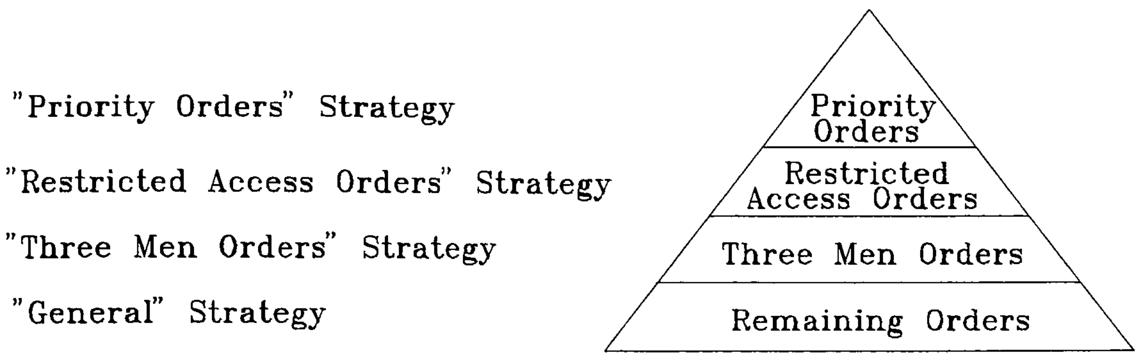

Figure 7.2: *Visit* strategy file

Roadshow: *Roadshow* was developed and first marketed in the United States of America where it enjoys great popularity. The system became available on the British market in 1990. One of *Roadshow's* main features is its unique and visually impressive road database, designed in combination with scanned colour road maps. Unique too is its hardware configuration, consisting of a laser videodisk player used for accessing the road map data. The system uses two VDUs, one of which is mouse-driven and serves to display the road maps including the set-up customer locations and route map information such as specified geographical zones. The other VDU is mainly keyboard-driven and used for the display of text. The system has a multi-depot functionality simultaneously planning routes for several depots on the basis of opportunity costs. The opportunity costs are the costs of delivering the order from one depot compared with the costs of delivery from other depots. Worth mentioning too are the system's comprehensive management information reports and a satellite vehicle tracking facility.

Optrak: The *Optrak* system is a relatively new UK-developed product which was first released to the British market in 1992. One of its major features is that it is designed to run in the convenient and user-friendly Microsoft Windows environment. The system is supplied with a range of digitised road map files at different scales; they include the UK, Europe and certain Metropolitan areas. The standard UK data base is the Bartholomew 1:125,000 digital map database including approximately 120,000 road nodes and 180,000 road links. In contrast, the standard UK road databases of other CVRS packages (excluding *Roadshow*) available on the British market include only between 15,000 and 40,000 road nodes and 25,000 and 65,000 road links.

Optrak is a modular system allowing the user to purchase just those features required, while providing expansion and specialised modules for more complex distribution operations. Modules include multi-day planning, refrigerated vehicles and multi-compartmented tankers. The trip/driver database module provides detailed analysis of performance criteria over a period of time. *Optrak* is both an operational and strategic-tactical tool. Its strategic-tactical analyst workbench provides a *script and query facility* which is comparable to the strategy files in *Visit* and enables the user to rapidly select or modify orders, vehicle types, customer restrictions etc. for modelling purposes. Multiple operations can be condensed into a single macro script and incorporated directly into the menu system.

The results of the comparative studies are presented below[16]:

- ***Visit* versus *Roadshow***

  Ease of implementation and maintenance: A particularly time-consuming task involved in the implementation of *Roadshow* is the set-up of its road database. The road nodes and links are not readily available as in *Visit* and other CVRS packages. Instead, the user needs to define each node and link via the computer mouse in connection with the scanned road maps provided. Road nodes are determined by pinpointing with the mouse on a desired location (typically a road junction) on the scanned map displayed. Road links are defined by moving the mouse along selected roads on the scanned maps.

  Overall, however, the implementation of *Visit* is more time consuming than that of *Roadshow*. This is mainly due to the need to define and maintain the strategy files. Also, time needs to be spent on customising the road database of *Visit*, as the level of road detail available has turned out to be insufficient for particular distribution areas.

  User interface: The *Roadshow* package is highly complex in terms of the number and comprehensiveness of technical features in combination with the predominantly keyboard-driven user menu. As a result, the operation of *Roadshow* tends to be a

16 The following discussion relies purely on the information provided by Brewery-C. No attempt has been made by the author of this research to investigate the validity of the information provided. However, with regard to the brewery's independent status, extensive experience in CVRS and up-to-date knowledge of the market, the information provided can be considered as genuine and reliable.

cumbersome procedure. Therefore, *Roadshow* is considered to be overall less user-friendly than Visit[17].

Control over the route generation process: *Roadshow* provides some control parameters such as territory grouping or specification of the number of trips per route. However, it fails to provide a feature similar to the strategy programming language in *Visit.* Also, the *Roadshow* system provides fewer options to define individual customers or groups of customers as appropriate. This gives the *Roadshow*-user limited control over route generation algorithms. As a result, the software frequently produces an unacceptable route geography which appears to be caused by the algorithm's tendency to generate petal-shaped routes. For example, in *Roadshow* a set of customers located in close proximity to one another may be delivered to by several vehicles as opposed to by a single vehicle. In "live" operations such route geography tends to reduce the overall transport productivity and, perhaps most importantly, leads to the rejection of the system by the distribution staff and drivers. The problem of unacceptable route geography can be partly resolved by the use of the territory grouping facility available in *Roadshow.* Nevertheless, *Visit* remains clearly superior in this area.

Planning speed: The route generation speed of *Roadshow* is considerably higher than that of *Visit.* While *Visit* may require 20 minutes for a particular planning scenario, *Roadshow* copes with this in less than two to three minutes. The longer planning period of *Visit* occurs in conjunction with the use of general control parameters and, in particular, the use of *strategy files.* Hence, the benefits of *Visit's* control features need to be traded off against its reduced planning speed.

Quality of the road database: The road database of *Roadshow* is considerably more flexible, detailed and accurate, as well as easier to set up and maintain than that of *Visit.*

Quality of the planning results: The two systems generate routes with nearly identical route times and distances as well as vehicle utilisation.

Conclusion: Brewery-C considers *Visit* to be more suitable for its specific requirements than *Roadshow.* This is mainly due to *Visit's* strategy planning language allowing for the necessary control over the planning algorithm.

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[17] The results on "user interface" will be further discussed in relation to *hypothesis 11g* regarding **CVRS operators' performance** (Section 7.5.1, pp. 243-244 and Section 7.5.3, pp. 248-250).

Nevertheless, *Roadshow* has some extremely attractive features, in particular its excellent road database, comprehensive management information reports, simultaneous multi-depot planning option and satellite tracking facility. Further enhancement of the package may upgrade its relative system quality (i.e. system quality in relation to the specific requirements of Brewery-C) and thus render it equal or even superior to that of *Visit*.

- ***Visit* versus *Optrak***

Ease of implementation and maintenance: Due to *Optrak's* effective Windows-based data handling facilities, the software is more convenient and quicker to install than *Visit*. Also, the facility to control the planning algorithm is considerably easier and quicker to use in *Optrak* (*query and script function*) than in *Visit* (*strategy programming language*).

User interface: The user interface of *Optrak*, with its convenient Windows environment, is clearly superior to that of *Visit* [18].

Control over the route generation process: Overall, *Optrak* allows for better control over the planning algorithm than *Visit*. In terms of effectiveness, the *query and script function* in *Optrak* matches, or even surpasses, the *strategy programming language* in *Visit*.

Planning speed: *Optrak* generates a complete set of routes, even in combination with the somewhat restrictive effect of the *query and script function*, at an exceptional speed, which is more than 10 times higher than that of *Visit*. This allows for considerable savings in personnel costs for the system operators. At the same time, it is possible to test various planning scenarios with different sets of parameters in order to identify the optimum planning results.

Quality of the road database: The standard *Bartholomew* road database incorporated in *Optrak* is considerably superior in every respect to the road map file in *Visit*. In particular, the "visual scheduling" and powerful graphics interface in *Optrak* makes route editing and manual scheduling both easy and intuitive.

[18] The results on "user interface" will be further discussed in relation to *hypothesis 11g* regarding **CVRS operators' performance** (Section 7.5.1, pp. 243-244 and Section 7.5.3, pp. 248-250).

Quality of the planning results: The route times and distances as well as vehicle utilisation of routes generated by *Optrak* match and, in some instances, slightly surpass those achieved by *Visit.* It is currently unclear, however, whether these differences in performance are real or a result of the systems' road databases. Further testing will be undertaken to evaluate this issue.

Due to the extremely high user-friendliness of *Optrak*, the package is likely to allow the schedulers working in day-to-day operations at the depot level to achieve higher **system operators' performance** (i.e. the schedulers' understanding of and ability to effectively use the software) than they currently manage to achieve under *Visit.* If this were the case, *Optrak* might lead to higher savings (**organisational efficiency**) than has been indicated by the present comparative study which was carried out by the centralised logistics department of Brewery-C[19].

Conclusion: Overall, Brewery-C judges *Optrak* as superior to *Visit.* The main advantages are the better planning results, the sophisticated road databases and the efficiency as well as user friendliness of the *query and script function.*

- **Potential replacement of the *Visit* system**

The *Roadshow* package fails to provide cost savings exceeding those achieved by *Visit,* currently used by Brewery-C. Consequently, at the present time *Roadshow* is no alternative to *Visit.*

Less clear-cut is the decision whether or not to replace *Visit* by the *Optrak* package. Judged on the basis of the current test results, *Optrak* is slightly more cost effective in terms of vehicle mileage covered as well as vehicle utilisation by time and weight or volume. Also, the annual support costs of *Optrak* would be approximately £30,000 lower than those of *Visit* (see subsequent Figure 7.4). Nevertheless, the relative cost advantage of *Optrak* is insufficient to justify the software's full investment costs of around £700,000 including expenses arising from the licence and implementation of the software (see subsequent Figure 7.3) which would arise in the event of replacing *Visit.*

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[19] This aspect will be further discussed in relation to *hypothesis 11g* regarding **CVRS operators' performance** (Section 7.5.1, pp. 243-244 and Section 7.5.3, pp. 248-250).

Brewery-C will re-examine both the *Roadshow* system and the *Optrak* system in the near future. Given the convenient Windows-based design of *Optrak*, this package is considered to offer the best potential for future developments.

The systems' licence and implementation costs as well as their annual support costs are compared in Figures 7.3 and 7.4 respectively. It should be noted that in Figure 7.3 the licence and implementation costs of *Visit* are not directly comparable with the equivalent costs of *Roadshow* and *Optrak* (subsequently referred to as "alternative CVRSSs"). This is because the costs of *Visit* are given at *historical* prices (cost which occurred when the software was purchased and implemented in the past). In contrast, the costs of the alternative CVRSSs are indicated at *current* prices.

It is interesting to note that the cost of a *Visit* user-licence at *historical* prices is higher than the costs of a user-licence for *Roadshow* and *Optrak* at *current* prices. Given the fact that the costs of CVRS technology have generally risen over the past years, it can be assumed that the cost of a *Visit* user-license offered to Brewery-C at *present* prices would also be the highest among the three packages. Support for this assumption is provided by the general list prices indicated by the CVRS suppliers within this research. According the list prices, a single installation of the *Visit* system is comparatively expensive in terms of both the software user-licence (£30,000) and the implementation support (£30,000)[20].

The implementation costs of the alternative CVRSSs *Roadshow* and *Optrak* shown in Figure 7.3 are estimates. These costs are lower than those of *Visit*, partly because, due to the existence of CVRS throughout the brewery group, most of the distribution data and data interfaces required by the alternative CVRSSs are readily available. Moreover, the alternative CVRSSs will require substantially less consultancy service on the part of the suppliers than was, in the case of *Visit*, initially required for the development of the *strategy files*.

[20] See Table A6-1 (Appendix 6), p. A-38.

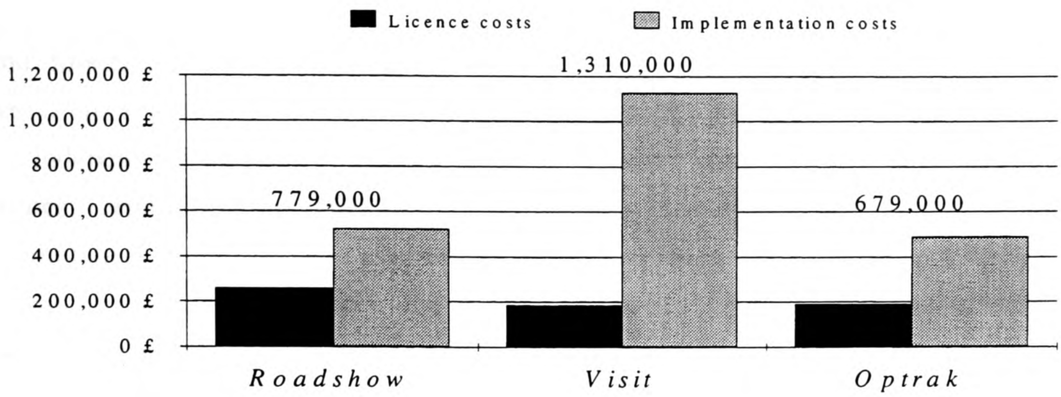

Figure 7.3: CVRS licence and implementation costs at Brewery-C

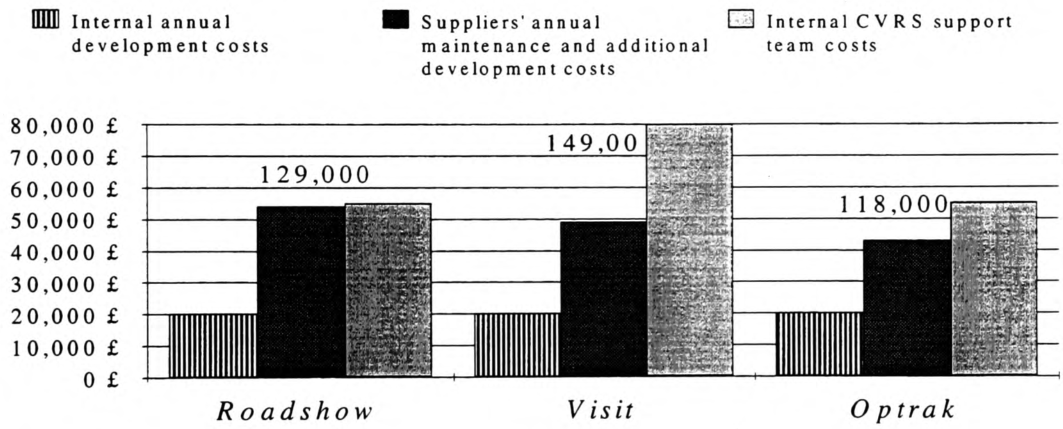

Figure 7.4: CVRS annual support costs at Brewery-C

In conclusion, the above evidence, in particular the comparative study conducted by Brewery-C, suggests that **organisational efficiency** in terms of transport cost savings and personnel costs of system operators is influenced by the (relative) quality of CVRS packages (**CVRS system quality**).

7.3.4 Summary

The survey data provide quantitative evidence to support *hypothesis 8c*. The data suggest a significant to moderately significant difference in **drivers' performance** between CVRSSs which achieved reductions in transport costs savings and CVRSSs which failed to do so (**organisational efficiency**). Regarding causality, it is likely that **drivers' performance** influences **organisational efficiency**.

Good and moderate qualitative evidence was provided for *hypotheses 8a* and *8b* respectively. The results suggest positive associations between **organisational efficiency** and the independent variables **CVRS system quality** and **CVRS operators' performance. Organisational efficiency** is most likely to be a result of the independent variables combined. The qualitative evidence of *hypothesis 8a* is further substantiated by the statistically founded evidence provided by the German transport society **Gesellschaft für Verkehrsbetriebswirtschaft und Logistik** (**GVB**).

7.4 Variables associated with CVRS user satisfaction

7.4.1 Presentation of variables

CVRS pre-attitudes: A number of research projects have associated favourable attitudes and perceptions of IT with several dimensions of system success. Ginzberg [1981b, p. 475] reveals "that users who hold realistic pre-implementation expectations about a system are more likely to regard that system as satisfactory and to use it". Lucas [1975] finds a positive correlation between user attitudes and perceptions of information systems on the one hand and the level of system usage on the other. Hence, there is good reason to assume that favourable CVRS pre-attitudes (pre-implementation attitudes of CVRS) lead to high levels of satisfaction with CVRS on the part of the managers, schedulers and drivers.

Organisational efficiency: Baroudi et al [1986] provide significant evidence for the expected impact of user satisfaction on the level of system usage by which the authors operationalise system success. Bargl [1994] provides significant evidence for the positive association between user satisfaction with CVRS (acceptance) and a change in personnel costs for vehicle schedulers which he considers to be a dimension of CVRS success. He does not specify the direction of the association, assuming that the variables influence each other mutually.

In the light of the above evidence, the current research expects that effective CVRSSs which produce transport cost savings (**organisational efficiency**) influence managers' and schedulers' **satisfaction** with the software. No such association is expected regarding the drivers, as these are unlikely to realise and appreciate the software's impact on **organisational efficiency**. Contrary to Bargl's findings, the association is not expected to be mutual or two-sided. As discussed in the previous section, **organisational efficiency** is most likely to be contributed to by three concepts:

- **CVRS system quality**;
- **CVRS operators' performance;** and
- **drivers' performance**.

The assumed associations between **CVRS user satisfaction** and **CVRS pre-attitude** as well as between **CVRS user satisfaction** and **organisational efficiency** form the following hypotheses:

> ***Hypotheses 9a - 9c***: The
> - managers' satisfaction with CVRS (9a)
> - schedulers' satisfaction with CVRS (9b)
> - drivers' satisfaction with CVRS (9c)
>
> is positively associated with their attitude towards CVRS prior to the software's installation (CVRS pre-attitude)

> ***Hypotheses 10a - 10b***: The
> - managers' satisfaction with CVRS (10a)
> - schedulers' satisfaction with CVRS (10b)
>
> is positively associated with the impact of CVRS on organisational efficiency.

7.4.2 Measurement of variables

Operationalisation of concepts

The operationalisations of the **organisational efficiency** concept and **CVRS user satisfaction** concept have previously been shown in Table 7.1 and Table 7.2

respectively[21]. The operationalisation of the **CVRS pre-attitude** concept has already been illustrated in Tables 6.7 to 6.10[22].

Selection of scales and indices

The **CVRS user satisfaction** and **CVRS pre-attitude** concepts are measured by an index comprising several indicators each of which is based on a *semantic differential seven-point scale*. Again, the managers and the schedulers responded on behalf of the drivers as a whole with the rankings given to each driver-specific indicator being averaged.

Data analysis

Hypotheses 9a to *9c* and *10a* to *10b* are tested by the *Spearman's rank correlation coefficient* and the *Kruskal-Wallis procedure* respectively.

7.4.3 Results

The results regarding *hypotheses 9a to 9c* and *hypotheses 10a* to *10b* are shown in Tables 7.22 to 7.23 and Tables 7.24 to 7.25 respectively.

Hypotheses 9a - 9c

Dependent variable	Independent variable	RCC	Sign. level
Concept	**Concept**		**(p in %)**
Managers' CVRS satisfaction	Managers' CVRS pre-attitude	0.35	**5**
Schedulers' CVRS satisfaction	Schedulers' CVRS pre-attitude	0.24	**10**
Drivers' CVRS satisfaction	Drivers' CVRS pre-attitude	0.33	**5**

Table 7.22: Spearman's rank correlation test for *hypotheses 9a, 9b and 9c*

21 See Table 7.1 and 7.2, pp. 184-185.

22 See Tables 6.7 to 6.10, pp. 153-154; see also Table 6.3 (p. 150) and further detail on the construction of the **CVRS pre-attitude** indices (Section 6.3.2, p. 153).

The data support the assumption that **CVRS pre-attitude** is positively associated with **CVRS user satisfaction** on the part of managers, schedulers and drivers (Table 7.22). Regarding the direction of the causal relationship, the pre-attitude towards the software has to precede the satisfaction with the software in time. Therefore, **CVRS pre-attitude** contributes to **CVRS user satisfaction.**

It is important to point out that the association found between **CVRS pre-attitude** and **CVRS user satisfaction** of drivers can only be considered as an indication rather than firm evidence[23].

Table 7.23 summarises the concepts' average scores[24].

Concept	Mean score	Max. score obtainable
Managers' CVRS satisfaction	5.7	7
Schedulers' CVRS satisfaction	5.4	7
Drivers' CVRS satisfaction	3.7	7
Managers' CVRS pre-attitude	5.3	7
Schedulers' CVRS pre-attitude	4.8	7
Drivers' CVRS pre-attitude	3.1	7

Table 7.23: Mean scores of CVRS user satisfaction and CVRS pre-attitude

Hypotheses 10a - 10b

Dependent variable	Independent variable		
	Organisational efficiency		
Concept	Transport cost savings	No transport cost savings	Sign. level (p in %)
	Rank	Rank	
Managers' CVRS satisfaction	23.0	8.9	**1**
Schedulers' CVRS satisfaction	26.6	17.9	**10**

Table 7.24: Kruskal-Wallis test for *hypotheses 10a, 10b*

The data suggest that **managers' CVRS satisfaction** and **schedulers' CVRS satisfaction** are higher at significant to moderately significant levels at sites which managed to reduce transport costs than at those which failed to do so (Table 7.24).

23 The reader is reminded that the findings regarding drivers' cognitive processes or mental states are not based on responses given by the drivers themselves, but by the managers and schedulers who responded on behalf of their organisations' drivers. See Section 1.4.1.2, pp. 21-22.

24 For further detail see Table A2-10 (Appendix 2), p. A-32.

Similarly to the previous *Hypothesis 2.23* the results regarding the drivers' satisfaction and pre-attitudes need to be considered as indicative only[25].

Table 7.25 summarises the average scores of the **CVRS user satisfaction** concepts differentiated by sites which managed to achieve transport costs saving and those which failed to do so[26].

Concept	Sites which achieved transport cost savings	Sites which failed to achieve transport cost savings	Max. score obtain-able
	Mean score	Mean score	
Managers' CVRS satisfaction	6.0	4.7	7
Schedulers' CVRS satisfaction	5.6	4.3	7
Drivers' CVRS satisfaction	3.9	3.2	7

Table 7.25: Mean scores of *CVRS user satisfaction*

As far as the direction of the causal relationship is concerned, there is good reason to assume that **organisational efficiency** influences **CVRS user satisfaction** and not vice versa.

For instance, **managers' CVRS satisfaction** is unlikely to directly influence **organisational efficiency**, because managers are not involved in operating the software. However, some indirect influence of **managers' CVRS satisfaction** on **organisational efficiency** may arise from the possibility that satisfied managers are more likely to undertake favourable measures (e.g. training, financial and non-financial rewards for schedulers and drivers, management support, allocation of clear responsibilities, regular meetings etc.) which aim to enhance the **CVRS operators' performance** and **drivers' performance**.

Similarly, **schedulers' CVRS satisfaction** and **drivers' CVRS satisfaction** are expected to have only an indirect impact on **organisational efficiency** in that CVRS satisfaction may influence **drivers' performance** and **CVRS operators' performance**. The latter two concepts in turn are expected to influence **organisational efficiency**[27].

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25 See footnote 23, p. 39.

26 For further detail see Table A2-7 (Appendix 2), p. A-31.

27 See *hypotheses 8 b* and *8c* (Section 7.3.1), p. 220f.

7.4.4 Summary

The data gives significant evidence to support *hypotheses 9a* and *9c* stating that the **managers' CVRS pre-attitude** and the **drivers' CVRS pre-attitude** respectively is significantly and positively associated with their **CVRS satisfaction**. Moderately significant evidence is found for *hypothesis 9b* proposing that the **schedulers' CVRS pre-attitude** is positively associated with their **CVRS satisfaction**.

There is good reason to predict *a priori* that **individuals'** (i.e. managers', schedulers', drivers') **CVRS pre-attitude** is a contributory cause of **CVRS satisfaction**.

The data also gives highly significant to moderately significant evidence to support *hypothesis 10a and hypothesis 10b* respectively. The data suggest that **managers' CVRS satisfaction** and **schedulers' CVRS satisfaction** (subsequently referred to as "**CVRS user satisfaction**") is higher at sites which achieved transport cost savings from using CVRS than at sites which did not (**organisational efficiency**). Again, it can be reasoned *a priori* that **organisational efficiency** is more likely to be a contributory cause of **CVRS user satisfaction** than vice versa.

The findings regarding the drivers need to be considered as <u>indications</u> only, because the associated data has been supplied by the managers and schedulers who have responded on behalf their organisations' drivers.

7.5 Variables associated with CVRS operators' performance

7.5.1 Presentation of variables

Training: Mykytyn [1988, p. 35] has assessed the perceived value of training of 49 financial managers using DSS. The study's results suggest that "training may certainly be an important ingredient for successful DSS usage in terms of decision-making effectiveness". Goslar et al [1986, p. 88] report more differentiated findings. Their study indicates that "DSS training may need to include decision-making and logic training *in addition* to technical instruction if users are to take full advantage of DSS capabilities".

The current study's qualitative findings also highlight the importance of computer training. Prior to operating a CVRSS, many schedulers had limited or no computer experience. Some schedulers also blamed their poor understanding of the software on their limited or, at the most extreme, lack of training. It is hypothesised, therefore, that specialised **CVRS training** influences the **system operators' performance**.

CVRS user satisfaction: The recent study of Bargl [1994] suggests that CVRS operators with high levels of CVRS acceptance (satisfaction) achieve higher reductions in the VRS period than operators with low levels of CVRS acceptance.

Similarly, there is good reason to hypothesise that schedulers who are satisfied with their CVRSSs are likely to have a high motivation and interest in learning to understand the software and thus achieve a high performance.

Individual differences: The impact of **individual differences** or **personal characteristics** on the success of MISs and DSSs have been the subject of a great number of past studies [Fürst, 1979; Lucas, 1975; Zmud, 1979a, b; Ein-Dor and Segev, 1981]. Bargl [1994] investigated the impact of the CVRS operators' school education, general computer experience and CVRS operating experience on the reduction in personnel costs for schedulers. However, none of the tested associations were found to be significant.

The current research expects the **CVRS operators' performance** to be associated with the following variables:

- **School education:** Individuals with a high level of school education have theoretical computer knowledge and/or a good understanding of mathematical and technological principles. Since CVRS technology is complex, based on mathematical programming, school education is expected to be positively associated with the CVRS operators' performance.

- **Educational computer training:** Individuals with educational training (college/in-house) on computers are more likely to achieve a favourable CVRS operating performance.

- **Computer literacy:** Individuals with experience and/or a good understanding of computers are more likely to achieve a favourable CVRS operating performance.

- **Work experience in VRS**: Fürst's [1979] empirical study shows that the number of years of experience in the same position is positively associated with the specific usage of DSSs[28]. VRS is a highly complex task which requires a comprehensive knowledge of the distribution environment. Therefore, the schedulers' length of experience in VRS is expected to be positively associated with their CVRS operating performance.

CVRS system quality: It is speculated that **CVRS operators' performance** (i.e. the schedulers' understanding of and ability to effectively use the software) is positively associated with **CVRS system quality** in terms of the software user interface.

An example of a study supporting this assumption is provided by a recent comparative study of work productivity among users of *Apple Macintosh* computers and *Intel*-based personal computers running *Microsoft Windows* [Arthur D. Little, Inc., 1994]. The *Macintosh* and *Windows* users involved in the study had comparable skill levels and were given an identical set of business computing tasks. Work productivity was measured along two dimensions: completion time and work effectiveness in terms of the degree to which the tasks were completed correctly.

The study suggests that the productivity of the software users is significantly influenced by the architecture of computers and the software user interfaces. In fact, despite the higher processor speed of the *Intel*-based personal computers running *Windows*, the test results show that the *Macintosh* computers provide a more productive environment, both for accomplishing common day-to-day tasks and for tasks that are done less frequently. Moreover, for the range of tasks tested, users on the *Macintosh* platform consistently outperformed the users on *Windows*, in terms of both completion time and effectiveness.

The apparent association between work productivity and the design of the software user interface can be considered as an indicator of the impact of **software quality** on the users' understanding and handling of software packages. In other words, software users appear to understand and handle best those software systems which have efficient user interfaces or operating environments.

Due to the lack of a valid measure of **CVRS systems quality**[29] the expected relationship between this variable and **CVRS operators' performance** will be validated with

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[28] Fürst differentiates between general and specific system usage. General usage refers to generation of routine reports, specific usage to the generation of personally initiated reports.

[29] See Sections 6.5.2 (pp. 176-177), 7.3.1 (pp. 218-219) and 7.3.3 (pp. 224-235).

qualitative evidence provided by the case studies rather than by quantitative evidence from the survey.

The above variables form the following hypotheses:

***Hypotheses 11a - 11g*:** CVRS operators' performances are positively associated with:

- CVRS satisfaction (*hypothesis 11a*);
- specialised training on the software - "CVRS training" (*hypothesis 11b*)
- educational (college/in-house) computer training (*hypothesis 11c*);
- school education (*hypothesis 11d*);
- computer literacy (*hypothesis 11e*);
- work experience in VRS (*hypothesis 11f*); and
- CVRS system quality ((*hypothesis 11g*).

7.5.2 Measurement of variables

Operationalisation of concepts

As outlined above[30], the **CVRS system quality** concept has not been operationalised for use in the survey. The operationalisations of the **CVRS operators' performance** concept and the **CVRS user satisfaction** concept have been shown previously in Table 7.16[31] and Table 7.2[32] respectively.

The operationalisation of the concepts relating to CVRS training and individual differences is presented in the following Tables 7.26 to 7.30.

Concept	Dimension	Indicator (contents)	Indicator (label)
CVRS training	(not applicable)	Extent of CVRS training	L-97
		Sufficiency of CVRS training	L-98

Table 7.26: Operationalisation of the *CVRS training* concept

30 See Section 7.5.1, pp. 243-244.

31 See Table 7.16, p. 221.

32 See Table 7.2, p. 185.

Concept	Dimension	Indicator (contents)	Indicator (label)
Educational computer training	(not applicable)	Extent of educational (college/in-house) computer training	M-58

Table 7.27: Operationalisation of the *educational computer training* concept

Concept	Dimension	Indicator (contents)	Indicator (label)
School education	(not applicable)	Types of schools attended, qualifications obtained	T-195x

Table 7.28: Operationalisation of the *school education* concept

Concept	Dimension	Indicator (contents)	Indicator (label)
Computer literacy	Computer knowledge	General comprehension of computers	M-56
	Computer experience	Level of computer usage	M-57

Table 7.29: Operationalisation of the *computer literacy* concept

Concept	Dimension	Indicator (contents)	Indicator (label)
Work experience in VRS	(not applicable)	Number of working years in VRS	U-164

Table 7.30: Operationalisation of the *work experience in VRS* concept

Formation of scales and indices

The **CVRS training** concept (Table 7.26), **educational computer training** (Table 7.27) concept and **computer literacy** concept (Table 7.29) are measured on a *semantic differential seven-point scale*. Since the indicators of the **CVRS training** concept correlate highly, they are averaged to form a **training index**. Similarly, the **computer literacy** dimensions and associated indicators correlate highly and are, therefore, averaged to form an *overall* **computer literacy** index.

The **school education** concept (Table 7.28) is measured by one indicator (T-195x) based on a nominal scale. It includes several levels of school education and degrees of higher education each of which accounts for a score as shown in Table 7.31. The respondents' qualifications are determined by the score of their highest level of qualification. For instance, respondents with no school qualifications after leaving school are rated 1. Respondents with a post-graduate degree of higher education are rated 4.

Level of school qualification	Score
No further qualification on leaving school or afterwards	1
'O' level/GCSE	2
'A' levels	3
Professional, vocational or technical qualification (BTEC, C & G, HND, HNC, ONC etc.)	3
First degree of higher education	4
Post-graduate degree of higher education	4

Table 7.31: Formation of a *school education* index

The **work experience in VRS** concept (Table 7.30) is measured by an indicator based on the numbers of years the schedulers have been involved in VRS during their total career.

Reliability and validity of measurement

The above **CVRS training index** and overall **computer literacy index** are considered reliable and valid measures as discussed below:

CVRS training index: R*eliability* or *internal consistency* of the **CVRS training** index is emphasised by a high *Cronbach Alpha coefficient* of 0.92 which is well above the minimum level of 0.8. *Construct validity* of the index is highlighted by *factor analysis* which facilitates the extraction of a single factor. Each indicator has a substantially higher factor loading than the minimum score of 0.6. Further support is given by the overall high correlation (*total score correlation*) between individual indicators and the sum of the other indicators (Table 7.32).

Indicator (Content)	Factor loading	Total score correlation	p %
Extent of CVRS training	0.96	0.78	1
Sufficiency of CVRS training	0.96	0.78	1

Table 7.32: Factor analysis and total score correlation for testing construct validity of the *CVRS training* index

Computer literacy index: R*eliability* or *internal consistency* of the **computer literacy** index is emphasised by a high *Cronbach Alpha coefficient* of 0.88 which is well above the minimum level of 0.8. *Construct validity* of the index is highlighted by *factor analysis* which facilitates the extraction of a single factor. Each indicator has a substantially higher factor loading than the minimum score of 0.6. Further support is given by the overall high correlation (*total score correlation*) between individual indicators and the sum of the other indicators (Table 7.33).

Indicator (Content)	Factor loading	Total score correlation	p %
General comprehension of computers	0.94	0.77	1
Level of computer usage	0.94	0.77	1

Table 7.33: Factor analysis and total score correlation for testing construct validity of the *computer literacy* index

Data analysis

Hypotheses 11a to *11f* are tested with the *Spearman's rank correlation coefficient.* Hypothesis *11g* is tested with qualitative evidence obtained from the case studies rather than statistically using data from the survey.

7.5.3 Results

Table 7.34 shows the results regarding *hypotheses 11a* to *11f.* The results regarding *hypothesis 11g* follow.

Dependent variable	Independent variable	RCC	p (%)
Concept	Concept		
CVRS operators' performance	Schedulers' CVRS satisfaction	0.30	**5**
CVRS operators' performance	CVRS training	0.24	**10**
CVRS operators' performance	Educational computer training	0.24	**10**
CVRS operators' performance	School education	0.04	ns
CVRS operators' performance	Computer literacy	0.15	ns
CVRS operators' performance	VRS work experience	0.08	ns

Table 7.34: Spearman's rank correlation test for *hypotheses 11a - 11f*

The mean scores of the concepts significantly associated with **CVRS operators' performance** at the 5% and 10% level are shown in Table 7.35[33].

Concept	Mean score	Max. score obtainable
CVRS operators' performance	5.7	7
Schedulers' CVRS satisfaction	5.4	7
CVRS training	4.1	7
Educational computer training	2.9	7

Table 7.35: Mean scores of concepts significantly associated with *CVRS operators' performance*

[33] For further detail see Table A2-11 (Appendix 2), p. A-32.

The comparison of the data highlights that the mean score of the **educational computer training** concept is significantly lower than the mean scores of the other concepts. This observation is confirmed by a look at this particular concept's response frequency shown in Table A2-11 in the Appendix 2. The individual responses and the medians are also comparatively low. This gives reason to suppose that, despite its statistical significance at the 10% level, the concept is unlikely to be associated with **CVRS operators' performance**. This is confirmed by further testing of the association with the parametric *Pearson Product Moment correlation coefficient* which suggests a non-significant association between the two concepts.

CVRS system quality

Qualitative evidence to support the expected association between **CVRS system quality** and **CVRS operators' performance** is provided by the previously mentioned comparison of the *Visit* package with the alternative systems *Roadshow* and *Optrak*[34]. With respect to the user interface of the packages the study suggests the following findings:

- ***Visit* versus *Roadshow***

  Since the *Visit* system is readily available as a brewery-version tailored to the actual requirements in brewery distribution, the user tends to become fairly quickly familiar with the system's layout and menu structure. In contrast, the screen and menu structure of *Roadshow* are not specifically designed for brewery distribution. Consequently, the average *Roadshow*-user requires a longer period to become familiar with the software than the average *Visit*-user. To compensate for this relative disadvantage of *Roadshow* in the case of the software's implementation in Brewery-C, the latter would require customisation of the package on the part of the software supplier.

  Except for the graphical display of routes and road database information in *Roadshow*, both systems are controlled via the keyboard. To be able to operate the software at a sufficient speed, the schedulers of both packages need to memorise various key-combinations. This can be handled by most users of *Visit* to a satisfactory extent. In the case of *Roadshow*, however, which is considerably more

[34] The study was previously mentioned in Section 7.3.3 (pp. 227-235) regarding the association between **CVRS system quality** and **organisational efficiency** (*hypothesis 8a*).

complex in terms of the number and comprehensiveness of technical features available, control via the keyboard tends to be cumbersome. This renders *Roadshow* overall less user-friendly and therefore considerably more difficult to understand as well as to handle than *Visit.*

To be able to use *Roadshow* at its full potential, the package obviously requires a more efficient user interface, which, ideally, is fully Windows-based and mouse-driven.

The operation of *Roadshow* is further complicated by the simultaneous use of two VDUs. The user needs to continuously swap between the one predominantly mouse-driven screen displaying the road or route graphics and the other keyboard-driven screen displaying text. On the other hand, the availability of two VDUs allows for more information to be displayed simultaneously than is possible in *Visit.*

- ***Visit* versus *Optrak***

Despite *Optrak* being more complex than *Visit* (and even slightly more complex than *Roadshow*) in terms of the number and comprehensiveness of technical features available to the user, *Optrak* is by far the more user-friendly system. This is due to the convenient Windows environment of *Optrak* which makes it a well integrated and clearly structured system which is easy to learn and to use. The latter in particular applies to users with previous experience with Windows-based software.

At a general level, the superiority of *Optrak's* user interface concerns the speed and detail with which the user is able to evaluate the results of particular planning scenarios. The results are displayed in the form of adjustable text windows which can be supported visually using the powerful graphical display facility. This organised and comprehensive availability of information allows the user to make manual decisions quickly and correctly. Also, due to the ease and speed by which parameters can be manipulated, the operator is inclined to test various planning scenarios with different settings, thus optimising the planning results. Moreover, the visual shell of *Optrak* offers an incentive for using the full range of facilities available. This makes *Optrak* both an interesting and effective planning tool.

A further area where the user interface of *Optrak* provides particular benefits is its *query and script function.* The latter is clearly structured, relatively easy to learn and, thus, can be handled by the local schedulers as appropriate. In contrast, the handling of the *strategy programming language* in *Visit* is extremely complex. It requires specialist-support from the centralised logistics department or the software suppliers.

The *query and script function* of Optrak is also extremely flexible. It not only allows for the control of the route generation algorithm, but also for convenient customisation of the screen and menu structure. This enables the user to tailor the user interface according to individual needs without having to rely on additional consultancy service.

The above findings suggest that the system operators' ability to understand and effectively operate CVRS packages (**CVRS operators' performance**) is influenced by the user interface of the software (**CVRS system quality**).

Most effective is a Windows-based user interface, as provided by the *Optrak* system. The benefits of such an effective user interface are expected to be of particular importance when the software is used in day-to-day operations at the depot level. Here the schedulers operate under extreme time pressure. The time required for "working on the mechanics" of the software needs to be kept to a minimum. To be able to take advantage of the planning options provided by the software, the schedulers must be able to use these quickly and effectively. The ready availability and structured presentation of information, ideally in the form of text and graphics, are crucial.

7.5.4 Summary

The data give significant quantitative evidence to support *hypothesis 11a* stating that **operators' performance** is positively associated with **schedulers' CVRS satisfaction.** A moderately significant association is found between **CVRS operators' performance** and **CVRS training** as proposed by *hypothesis 11b.*

The qualitative evidence provided by the comparative study of CVRS packages carried out by Brewery-C gives good support for *hypothesis 11g* suggesting that the schedulers' understanding of the software and ability to operate it (**CVRS operators' performance**) is influenced by the **CVRS system quality** in terms of the software user interface.

Regarding causality, there is good reason to predict *a priori* that **CVRS training** leads to **CVRS operators' performance.** Similarly, sound arguments can be found to assume that **schedulers' CVRS satisfaction** influences **CVRS operators' performance.** However, there is also some reason to suggest that **CVRS operators' performance** is a contributory cause of **schedulers' CVRS satisfaction.** Also, it is possible that there is a two-way causal link between the variables; that is, satisfied system operators are motivated to achieve high performance while, at the same time, high performance enhances the operators' satisfaction.

Since **CVRS system quality** precedes **CVRS operators' performance** in time, it can be safely predicted *a priori* that the performance is contributed to by the system quality rather than vice versa.

7.6 Variables associated with drivers' performance

7.6.1 Presentation of variables

CVRS user satisfaction: It is expected that the drivers' satisfaction with CVRS influences

- the drivers' performance in terms of their ambition, and probably also,
- their ability to meet the working standards indicated by the computer-generated routes.

Relationship drivers - schedulers: Evidence from the case studies of the current research suggests that the drivers' work behaviour is affected by their personal and working relationship with the schedulers, with whom the drivers tend to have the closest contact within the organisation. It is assumed, therefore, that the quality of this relationship positively influences the drivers' performance in terms of their ambition, and probably also their ability, to meet the working standards indicated by the computer-generated routes.

The above variables form the following hypotheses:

Hypotheses 12a - 12b **:** The drivers' performances are positively associated with their:

- relationship with the CVRS operators (*hypothesis 12a*); and
- satisfaction with CVRS (*hypothesis 12b*).

7.6.2 Measurement of variables

Operationalisation of concepts

The operationalisation of the **drivers' performance** concept and **CVRS user satisfaction** concept has been shown previously in Table 7.17[35] and Table 7.2[36] respectively.

The operationalisation of the **relationship between CVRS operators and drivers** concept (below referred to as "**relationship schedulers - drivers**") is displayed in the following Table 7.36.

Concept	Dimension	Indicator (contents)	Indicator (label)
Relationship schedulers-drivers	Personal relationship	Personal relationship between schedulers-drivers	N-63p
	Work relationship	Work relationship schedulers-drivers	N-64p
	Confidence	Drivers' confidence in schedulers	N-65p

Table 7.36: Operationalisation of the *relationship schedulers - drivers* concept

Selection of scales and formation of indices

The dimensions and associated indicators (N-63p-65p) of the **relationship schedulers-drivers** concept correlate highly, which gives reason to average them into an *overall* index.

Reliability and validity of measurement

The above *overall* **relationship schedulers-drivers index** is considered a reliable and valid measure as substantiated below:

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[35] See Table 7.17, p. 221.

[36] See Table 7.2, p. 185.

Reliability or *internal consistency* of the index is emphasised by a high *Cronbach Alpha coefficient* of 0.94 which is well above the minimum level of 0.8. *Construct validity* of the index is emphasised by *factor loadings* substantially higher than the minimum score of 0.6. Further support is given by the overall high correlation (*total score correlation*) between individual indicators and the sum of the other indicators (Table 7.37).

Indicator(Content)	Factor loading	Total score correlation	p %
Personal relationship between schedulers-drivers	0.93	0.87	1
Work relationship schedulers-drivers	0.96	0.90	1
Drivers' confidence in schedulers	0.93	0.76	1

Table 7.37: Factor analysis and total score correlation for testing construct validity of the *relationship schedulers-drivers* index

Data analysis

Hypotheses 12a and *12b* are tested with the *Spearman's rank correlation coefficient.*

7.6.3 Results

Table 7.38 shows the results regarding *hypotheses 12a* and *12b*[37].

Dependent variable Dimension	Independent variable Concept	RCC	p (%)
Drivers' performance A	Drivers' CVRS satisfaction	0.66	**1**
+ Drivers' performance B	Drivers' CVRS satisfaction	0.33	**5**
Drivers' performance A	Relationship schedulers - drivers	0.40	**5**
+ Drivers' performance B	Relationship schedulers - drivers	0.28	ns

Table 7.38: Spearman's rank correlation test for *hypotheses 12a - 12b*

The **drivers' CVRS satisfaction** concept is significantly to highly significantly associated with both dimensions of **drivers' performance**. Mixed results are available regarding these dimensions and the **relationship schedulers-drivers** concept.

The mean scores of the concepts and dimensions tested in the previous Table 7.38 are shown in Table 7.39.

[37] For further detail see Table A2-12 (Appendix 2), p. A-32.

Concept/Dimension	Mean score	Max. score obtainable
Drivers' performance A	4.3	7
+ Drivers' performance B	4.3	7
Relationships schedulers-drivers	5.9	7
Drivers' CVRS satisfaction	3.7	7

Table 7.39: Mean scores of *relationship schedulers-drivers* concept and *drivers' performance* dimensions

7.6.4 Summary

The data gives strong support to *hypothesis 12b* stating that **drivers' performance** is positively associated with **drivers' CVRS satisfaction**[38]. Mixed results are found regarding *hypothesis 12a* with a significant association existing only between the **drivers' performance A** dimension (drivers' ambition to meet the working standards indicated by the software) and the **relationship scheduler-drivers** concept.

Regarding causality, there is good reason to predict that both **drivers' CVRS satisfaction** and **relationship schedulers-drivers** precede **drivers' performance** in time and therefore influence the latter.

7.7 Overview of main empirical findings

Factors have been found to explain CVRS success from three perspectives:

CVRS success from a broad perspective

Successful systems are defined as systems which

- are being used while unsuccessful systems are abandoned;
- fit individual organisations' requirements while unsuccessful systems fail to do so;

[38] The reader is reminded that the findings regarding drivers' *cognitive processes* or *mental states* such as **CVRS satisfaction** and **CVRS pre-attitude** evaluated by individuals (managers and schedulers) other than the drivers themselves are considered as indications only rather than firm evidence. In contrast, with respect to *behavioural* variables such as **drivers' performance** the measurement by the managers and the schedulers on behalf of the drivers is considered to be a valid procedure as discussed earlier. See Section 1.4.1.2, pp. 21-22.

- lead to favourable feelings, attitudes and support amongst individuals involved during the implementation of the software while unsuccessful systems fail to do so.

This perspective of CVRS success has been analysed in relation to the quality of the proeess by which the software has been implemented. The **implementation** concept used is highly comprehensive, incorporating suggestions and ideas from past MIS/DSS implementation research.

The current study provides both qualitative and quantitative evidence that successful implementations of CVRS are related to a preponderance of favourable forces in each phase of the implementation.

Organisational efficiency

Whether CVRS facilitates the enhancement of **organisational efficiency** in terms of reducing transport costs is likely to depend on the interactive effect of three variables. These are:

- **CVRS operators' performance** - defined as the system operators' ability to effectively use the CVRSS

- **Drivers' performance** - defined as the drivers' demonstrated willingness and ability to meet the working standards indicated by the computer-generated routes.

- **CVRS system quality** - defined as the ability of the software to meet an organisation's requirements in VRS.

The current research provides quantitative evidence that **drivers' performance** is higher at sites which manage to reduce transport costs than at sites which fail to do so (**organisational efficiency**). Hence, a critical factor for achieving the full potential of CVRS is that the drivers adhere to the working standards suggested by the software.

Also some qualitative evidence is provided to support the assumption that **organisational efficiency** (transport cost savings) is affected by the **CVRS operators' performance** and the **CVRS system quality**.

Further quantitative evidence for the influence of **CVRS system quality** on **organisational efficiency** is available from a past laboratory research project. The project involved the testing of commercial CVRS packages with sets of empirical transport data provided by German-based fleet operators[39].

Individuals' satisfaction with the software

The study provides quantitative evidence that the managers', CVRS operators' and drivers' **CVRS pre-attitudes** are positively associated with their satisfaction with the software after its implementation (**CVRS satisfaction**). Regarding causality the findings suggest that **CVRS pre-attitude** contributes to **CVRS satisfaction**.

Quantitative evidence also suggests that the managers' and schedulers' **CVRS satisfaction** differ between sites achieving reductions in transport costs and sites failing to reduce costs (**organisational efficiency**); that is, the individuals are satisfied with the software if it allows for transport cost savings.

Organisational efficiency is likely to contribute to **CVRS satisfaction**. However, certain indirect feed-back effects are possible, in that CVRSSs which succeed in achieving transport cost savings and, therefore, lead to satisfaction may encourage individuals to undertake or develop positive measures and positive behaviour; these may involve regular updating of the CVRS distribution data and parameters or increasing **CVRS operators' performance** and **drivers' performance.** The latter in turn are likely to influence **organisational efficiency**.

The critical success factors of **CVRS operators'** and **drivers' performance** have been further investigated in relation to their cause:

CVRS operators' performance

- Quantitative findings suggest that schedulers who are satisfied with the CVRSS have a high competence in operating the software.
- Quantitative evidence also suggests that adequate training on the software is positively associated with the schedulers' effective handling of the software.
- Qualitative evidence suggests that the schedulers' understanding of the software and ability to operate it are positively associated with the quality of the CVRS system in terms of its user interface.

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[39] For further detail on the project see Bargl, 1994, 1992; Klaus, 1990.

A priori reasoning suggests that **CVRS operators' performance** is contributed to by the schedulers' **CVRS satisfaction.** Similarly, it is likely that **CVRS training** and **CVRS system quality** lead to **CVRS operators' performance**.

However, **CVRS operators' performance** may also lead to **CVRS satisfaction** on the part of the schedulers, because operators with a good understanding of the software are likely to be satisfied with it. It is also possible that there is a two-way causal link between the variables.

Drivers' performance

- The quantitative data give indications (although not firm evidence)[40] that drivers who are satisfied with their organisations' use of CVRS are more willing and able to meet the working standards indicated by the software.
- Quantitative evidence also suggests that the quality of the relationship between the schedulers and the drivers is positively associated with the drivers' ambition to meet the working standards indicated by the software.

Drivers' performance is likely to be influenced by both independent variables.

Figure 7.2 summarises all relationships between variables of the *CVRS success model* tested in the preceding sections. The relationships found to be significant and non-significant are indicated by continuous lines and dashed lines respectively.

Note that the relationships (marked with dotted lines) between **CVRS system quality** and **organisational efficiency** as well as between **CVRS system quality** and **CVRS operators' performance** have not been tested with quantitative evidence within the survey of the current study[41].

Table 7.40, which follows, summarises the hypotheses relating to the significant relationships.

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[40] See See Section 1.4.1.2, pp. 21-22.

[41] See Sections 6.5.2 (pp. 176-177), 7.3.1 (pp. 218-219) and 7.3.3 (pp. 224-235).

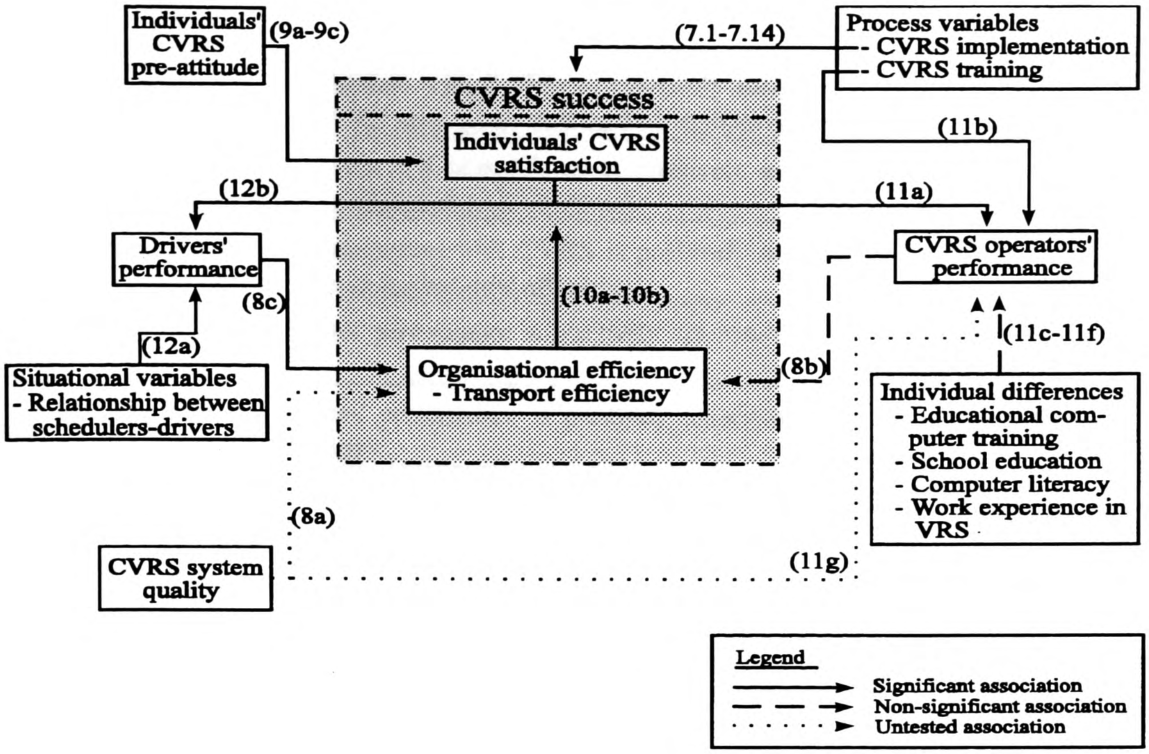

Figure 7.5: Overview of significant and non-significant relationships of the CVRS success model

	Hypotheses relating to the *CVRS success model*	**significance level (p in %)**
7 (7.1 to 7.14)	CVRS success is related to a preponderance of favourable forces in each phase of the implementation process[1].	1, 5, 10; sign. case study/expert interview findings
8c	Organisational efficiency is positively associated with the drivers performance	5, 10
9a	The managers' satisfaction with CVRS is positively associated with their attitude towards CVRS prior to the software's installation.	5
9b	The schedulers' satisfaction with CVRS is positively associated with their attitude towards CVRS prior to the software's installation.	10

[1] A hypothesis can have **several significance levels** if it is composed of several dimensions or sub-dimensions. If the majority of dimensions or sub-dimensions of a concept show significant findings, then the non-significant findings will be ignored in this table. Similarly, if the dimensions or sub-dimensions of concepts have equal numbers of significant and non-significant findings, the non-significant findings will be ignored if there is a preponderance of dimensions or sub-dimensions labelled *important* ("+") which are found to be significant.

Table 7.40: Significant hypotheses relating to the CVRS success model

9c	The drivers' satisfaction with CVRS is positively associated with their attitude towards CVRS prior to the software's installation.	5[1]
10a	The managers' satisfaction with CVRS is positively associated with the impact of CVRS on organisational efficiency.	1
10b	The schedulers' satisfaction with CVRS is positively associated with the impact of CVRS on organisational efficiency.	10
11a	The CVRS operators' performance is positively associated with their CVRS satisfaction.	5[1]
11b	The CVRS operators' performance is positively associated with specialised training on the software.	10
12a	The drivers' performance is positively associated with their relationship with the CVRS operators.	5, ns
12b	The drivers' performance is positively associated with their CVRS satisfaction	1[1], 5[1]

[1] The findings regarding the drivers' **CVRS pre-attitudes**, **CVRS satisfaction** and are not based on responses given by the drivers themselves, but by the managers and schedulers who responded on behalf of their organisations' drivers. Therefore the findings are considered as indications only as opposed to evidence. Compare Section 1.4.1.2, p. 21-22.

Table 7.40 (continued): Significant hypotheses relating to the CVRS success model

Chapter 8: Critical Evaluation of the CVRS Models and Opportunities for their Further Development

8.1 Introduction

The preceding Chapters 6 and 7 dealt with the development and validation of two *CVRS models* related to (1) the adoption of CVRS and (2) the success of CVRS respectively.

This Chapter will address the following issues:

- Evaluation of the contributions made by the development of the *CVRS models* and by the results obtained from the analysis of the data collected;
- Evaluation of the limitations of both the *CVRS models* as such and the data used for their validation. Special attention will be devoted to the relative importance of the variables investigated;
- Suggestions for further refinements of the *CVRS models*; and
- Demonstration of the potential of multivariate analyses within the *CVRS models*.

8.2 Contributions made by the CVRS models

The contributions of the *CVRS models* can be divided into (1) academic contributions and (2) practical contributions.

Academic contributions of the CVRS models

Past research has failed to provide established and validated models or theories concerning managerial issues relating to CVRS technology. Consequently, the work involved in the current research required the establishment of two new and unique *CVRS models*. Two main academic contributions were made:

- Firstly, evidence from past studies of various disciplines (OBB, OB, DSS, MIS) related to CVRS was analysed, systematised and consolidated. This is believed to have made a significant contribution to a *long-term multi-person* research effort.

- Secondly, research questions in relation to the adoption and success of CVRS can be complex, involving many interacting variables. The *CVRS models* of this study reflect this complexity and allow for its structured presentation. This is likely to serve future researchers as a guide to identifying and focusing on particularly critical or interesting variables. Such variables will not necessarily be those which in the current study were found to be "significant". Of equal or, perhaps, greater interest may be those variables which were shown to be non-significant despite the likelihood of their being significant (e.g. the associations between **individual differences** and **CVRS operators' performance**). In fact, the lack of statistical evidence to demonstrate the significance of relationships between variables is by no means conclusive for the non-existence of the relationships. The lack of evidence only means that no significant relationships were found from a given set of data using a particular measurement instrument.

  With a view to the future use of the *CVRS models*, these are also believed to provide a useful basis for the generation of new hypotheses. Ideally, such new hypotheses will be related to the existing ones, thus complementing the models' overall findings and conclusions.

Both *CVRS models*, in particular the *CVRS success model*, are essentially geared towards CVRS technology. At the same time, it should be noted that the models comprise various general classes of variables including their expected interrelations. This feature may allow the *CVRS models* to be also applied to IT systems in road transport other than CVRS, for instance, on-board computers or vehicle tracking systems.

Similarly, parts of the *CVRS models* may be related to areas other than road transport, for example IT in production, marketing or architecture. This may require certain modifications of the models. With respect to the *CVRS adoption model*, for instance, such modifications may concern **individual differences** or **structural (business) variables**; that is, the analysis of decisions regarding the adoption of a software system for use in marketing may require consideration of special personal characteristics relevant to this particular software. Also, companies from different sectors will differ in terms of their organisational structures.

Practical contributions of the CVRS models

The validation of the *CVRS models* with empirical data has highlighted the importance of certain variables for the adoption, implementation and subsequent use of CVRS technology. The conclusions derived from these findings suggest a set of practical measures which may be applied to overcome the CVRS user-gap and to ensure system success. The conclusions will be presented in the final Chapter 9[1]. The measures are addressed to three distinct groups:

- Potential and actual users of CVRS technology;
- Suppliers of CVRS technology; and
- Private and public organisations or institutions.

The empirical data used were collected from own-account fleet operators in the British brewing industry. The general conclusions, therefore, have full validity only for this particular sub-sector of road transport. However, it is reasonable to assume that some of the findings can also be related to road transport operators with transport problems and business structures similar to those investigated in this study. Two examples for such findings are:

- The importance of appropriate **CVRS implementation** for **CVRS success**; and
- The impact of **CVRS operators' performance**, **drivers' performance** and **CVRS system quality** on **organisational efficiency**.

8.3 Limitations and suggestions for further refinements of the CVRS models

8.3.1 Comprehensiveness of the models

Compared to many of the previously suggested *product adoption models* and *IT implementation/success models*, the proposed *CVRS models* are fairly comprehensive in terms of the number of variables which they include. Also, with regard to the financial and temporal constraints of a single study like the present one, investigation of a greater number of variables seems over-ambitious, if not unfeasible.

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1 See Section 9.2, p. 288f.

On the other hand, it would be unreasonable to claim entire completeness of the *CVRS models*. Modifications may be made in three areas:

- Firstly, further empirical testing of the models may suggest the necessity for deletion of some of the existing variables if these can be shown to be consistently without meaningful effects. This would help to "purify" the *CVRS models*.

- Secondly, new variables may be added to the models.

  Adding variables to the *CVRS adoption model* may enable the interactions between individuals in the organisational "buying centre" as well as between the organisational "buying centre" and the CVRS suppliers to be described. Important questions for future research could be:

  - Which stages in the CVRS adoption process are critical?

  - How strongly do the operational staff at the depot level influence **management decisions to adopt CVRS** in large organisations with several depots? In other words, to what extent are the **CVRS pre-attitudes** of the *managers with CVRS decision making authority* influenced by the **CVRS pre-attitudes** of the operational staff? Equally, what is the role of the **data processing department** or similar technical departments within the CVRS adoption process?

  - To what extent do **cognitive styles** and **personality characteristics** affect the **CVRS pre-attitudes** of CVRS decision makers?

  - How is an organisation's decision to **adopt CVRS technology** influenced by the quality of the **CVRS suppliers' consultancy service**? Do the suppliers manage to convincingly demonstrate the full potential benefits of their product? Which are the critical elements in the **CVRS buyer-supplier relationship**?

  - Which characteristics of the software determine the potential CVRS users' perceptions of **CVRS system quality**?

  With regard to the *CVRS success model*, new research variables may concern research questions such as:

  - What is the impact of **cognitive styles** and **personality characteristics** on the **CVRS operators' performance**?

- What are the dynamics among drivers concerning their acceptance of CVRS and thus their willingness to meet the working standards indicated by the software (**drivers' performance**)?

- Which components of **CVRS system quality** have the greatest effect on **organisational efficiency**? What is the relative importance of the components including, for example, the road data base, planning algorithm, graphical display features, user friendliness etc.?

- Thirdly, the *CVRS models* may be modified with respect to transport operators which differ from own-account operators in brewery distribution.

8.3.2 Measurement of variables

The measurement of variables has incurred a number of inherent difficulties which are summarised below:

Lack of measurement instruments: The study's basic measurement problem arose from the lack of readily available or standardised measurement instruments. It became necessary for the research project to find its own operational definitions of the variables used in the models. For most variables in the model this objective was achieved. An exception to this is the **CVRS system quality** variable. While conceptually this variable does not present a problem, operationally it does. A general problem with **CVRS system quality** is that it is relative to individual requirements in road transport. In other words, CVRS systems perform differently in different distribution environments which suggests the use of a relative measure of **CVRS system quality**. What are the relevant dimensions of such relative **CVRS system quality** that impact on **organisational efficiency**? This research has provided some basic suggestions to finding the answer to this question. However, due to the operational problems involved no attempt was made to put the suggestions made into practice and effectively measure relative **CVRS system quality**.

Criticism may arise concerning the chosen approach of using new measurement instruments which have not been validated in previous separate studies. While such criticism may essentially be justified, it applies to perhaps the majority of empirical studies in any discipline. Lucas et al [1990, p. 92] state: "Validated research instruments with demonstrated reliability are obviously important for progress in any area of research. However, in a developing field of research, it is often difficult to find validated measures already in existence for the constructs to be studied or to conduct a separate validation study". The authors conclude furthermore that even if standard measures were available, these would tend to be unsuitable for most investigations. For example, the evaluation of specific **CVRS satisfaction** with a standardised measure of **IT satisfaction** would probably fail to measure the true satisfaction to be evaluated. Bluntly speaking, standard measures will measure concepts in general and not their true or specific attributes. Again, concluding comments are given by Lucas and his co-researchers [1990, p. 92] who suggest: "The only answer we can offer to this dilemma is to try to develop the best instruments possible, using validated scales from other fields, where appropriate, but not ignoring important constructs simply because appropriate measures have not been previously developed and tested".

Especially challenging for future CVRS researchers and of practical relevance to road transport operators would be the development and validation of a test instrument for assessing the quality of the CVRS packages (**CVRS system quality**). Such a research instrument needs to comprise a set of representative VRS problems using data from different organisations and sectors of road transport. Preferably, the VRS problems should be differentiated by their levels of complexity. This measure could be used in laboratory experiments. The test results could serve the potential users of CVRS as a useful guide for an initial selection of those packages which appear to be most suitable for their requirements. Subsequently, these initially selected packages can be evaluated in further detail on the basis of the users' own transport data.

However, if such a CVRS test project were effectively put into practice, it would need to be carried out to a high standard and at regular intervals. The test procedure would also need to be overviewed by a group of independent researchers and practitioners in order to ensure that it does not represent one person's prejudice. Otherwise, the results could cause an enormous effect in the market, promoting one or a few suppliers and putting others out of business.

Weak relationships and sample size: The samples available in this study are generally small for statistical testing. The problem is compounded by the weakness of many of the relationships between variables or group differences in variables included in the models.

Most relationships and group differences (subsequently referred to as "relationships") were shown to exist as predicted by the (alternative) hypotheses. In some cases, however, the relationships are not significant, which may be a result of their overall weakness in combination with the small sample sizes. This problem is most obvious with regard to the association between **individual differences** and the **CVRS pre-attitudes** of managers <u>with</u> *CVRS decision-making authority*. By merging the small sample of these managers with the samples of managers <u>without</u> *CVRS decision-making authority* and schedulers, some of the initially insignificant relationships can be shown to be significant. Weak relationships together with small sample sizes are also a problem in the testing of CVRS implementation *hypotheses 7.1 to 7.14*. Again nearly all group differences are as expected; that is, the *Kruskal-Wallis test* performed suggests that successful CVRS installations have higher average rankings in the various implementation variables than unsuccessful installations.

Future research should ideally work with samples larger than the present ones. Sample sizes of more than one hundred units may be recommended. Less than this will probably also lead to some significant findings. However, some actually existing relationships between variables may remain undiscovered if the relationships are weak and the data available insufficient.

While large samples are always desirable, their actual achievement is usually no easy task. This particularly applies to self-completion mailed questionnaire research designs which are notorious for non-response. The problem is most serious if the total population is very small which is the case for the actual users of CVRS technology. A further problem is the inaccessibility of many of the CVRS users, mainly because there is sparse information available about their identity and location. The suppliers of the software are generally reluctant to disclose the identity of their customers. If they do, then these are usually the "CVRS flagships" where the software produces major benefits. CVRS system failures are unlikely to be revealed voluntarily. Therefore, CVRS studies based on organisations disclosed by the CVRS suppliers are probably highly biased.

<u>Variables concerning drivers:</u> The variables relating to the drivers have been measured with data supplied by the managers and schedulers who responded on behalf of the drivers. The current research has presented a number of practical, organisational and methodological reasons in favour of this procedure when applied to <u>behavioural</u> or <u>non-cognitive</u> variables. These include **drivers' performance** (i.e. extent to which the drivers demonstrate willingness and ability to adhere to the standards indicated by the computer-generated route plan) and **drivers' involvement** in the implementation of the software. Such variables can best be evaluated in the proposed manner: that is, by their superiors (managers) and close colleagues (schedulers).

This procedure is perhaps questionable when applied to variables concerning the drivers' mental states or cognitive processes, for example, **CVRS user satisfaction** (drivers' satisfaction with the software) and **CVRS pre-attitude** (drivers' pre-implementation attitude towards the software). Due to the risk of measurement error, the findings obtained from these variables are used as indications only rather than firm evidence.

The study of the role of the drivers in both the implementation and operational use of CVRS technology offers a great potential for future research. Such an undertaking would be clearly unique, extremely interesting and of considerable importance. On the other hand, it would also be a challenging task, because it requires the collection of several representative and, therefore, large samples of drivers per vehicle fleet investigated. Considerable difficulties can be expected in gaining the co-operation of sufficient fleet operators to allow for meaningful statistical analyses. Moreover, the researcher needs to have direct control over all phases of the data collection process including the selection of the samples. Finally, the researcher requires exact knowledge of the characteristics of the populations and associated samples being studied. Otherwise the risks of *bias* in the responses cannot be adequately estimated.

The above circumstances suggest that the future investigation of CVRS technology in connection with drivers will probably provide sufficient substance for the exclusive coverage by single studies of magnitudes comparable to that of the current study.

Independent versus self-reported measurement: The measurement of the majority of variables in the models relies on self-reported or subjective responses as opposed to independent or objective responses. The danger here is that for certain variables subjective evaluations can differ from objective evaluations. For instance, the schedulers' perceived ability to operate the software (**CVRS operators' performance**) can differ from their actual ability. Other examples are the operators' **computer literacy** and the amount of **CVRS training** provided. Again, differences may occur between the variables being measured subjectively by the respondents themselves and objectively by independent tests and observations. This problem, however, is bound to arise in most pieces of social research, particularly in studies involving the analysis of many variables. Independent or objective measures are rarely readily available and their development tends to be an extremely time-consuming as well as challenging task.

For future studies of the CVRS variables mentioned above independent measures are desirable, whenever this is methodologically possible and appropriate. To be feasible within the human and financial resources available, such studies may need to focus on fewer variables as opposed to taking a comprehensive research perspective as it is the case in the current study.

Of particular interest is further investigation of the impact of **individual differences** (including cognitive or decision-making styles, personality characteristics and demographic/situational variables) on **CVRS operators' performance**. Objective measurement of these variables with specialised tests may reveal significant relationships between the variables. Should this be true, then this would give researchers strong reason to suggest that the CVRS operators need to be selected with extreme care, perhaps by the use of psychometric testing. This would also suggest the need for upgrading the operators' job.

Longitudinal versus cross-sectional studies: Like most empirical studies the present research is cross-sectional as opposed to longitudinal in nature. Constraints from cross-sectional research can arise from two major sources:

- Firstly, individuals tend to forget details of facts, circumstances, feelings or attitudes over time. Therefore, data relating to past periods may not necessarily be measured with full accuracy, unless being recorded in physical documents or data files. This is the case regarding the pre-implementation attitudes towards CVRS (**CVRS pre-attitude**) of actual CVRS users. The CVRS users were asked to respond to the questionnaire items regarding their **CVRS pre-attitudes** retrospectively, that is in relation to the point in time prior to the installation of CVRS.

  While retrospective measurement of variables generally is not ideal, good practical and methodological reasons were provided to justify its use within this study[2].

- Secondly, cross-sectional research, particularly if carried out via self-administered questionnaires, generally fails to evaluate processes which tend to involve dynamically interacting factors. Cross-sectional research may at best capture processes in terms of general phases, but rarely in great detail. This problem has been encountered with regard to the measurement of **CVRS implementation**. The survey research using mailed questionnaires has failed to measure particular dimensions or factors such as the **staffs' feelings, attitudes and support demonstrated during the implementation process**. Similarly, the survey was

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2 See Section 6.2, pp. 146-148.

unable to evaluate the importance of **testing the software** in the "diagnosis phase" of the implementation.

The above problem has been significantly eased by the applied *triangulation of measurement* approach; that is, the case study research supplies useful findings in areas where the methodology of the survey is not completely appropriate. In addition, the evidence provided by the case studies confirms the findings suggested by the survey results.

Future CVRS research would strongly benefit from being designed as longitudinal studies. Only in this form would it be possible to investigate the processes involved in the adoption, implementation and success of CVRS in full detail. Unfortunately, longitudinal studies have a number of serious disadvantages, two of which are:

- Longitudinal studies often extend over long time periods. This particularly applies to the decision-making processes of whether to adopt CVRS technology and how to implement it. The CVRS adoption process, including the testing of the software, can itself take many months. Similarly, CVRS implementation requires approximately four months on average.

- In longitudinal studies, gaining the co-operation of organisations or individuals over long time periods can be a problem. The initial enthusiasm among key people may diminish quickly, putting the research project in jeopardy.

Multivariate analyses: The data available in the current study fail to meet certain requirements of multivariate statistics. This is predominantly a result of the relatively small sizes of the samples, together with the scales used for measuring the research variables.

Future studies would benefit from being designed in a way which provides data appropriate for multivariate analyses. Of particular interest is the analysis of the combined effect of the key variables of CVRS success, including **organisational efficiency**, **CVRS system quality**, **schedulers' performance** and **drivers' performance**. Other examples are the identification of personal characteristics (**individual differences**), in particular cognitive styles, which best predict **CVRS operators' performance**, **drivers' performance**, or the **CVRS pre-attitudes** of *CVRS* *decision makers.* Ideally, the variables should be evaluated with objective measures as opposed to subjective measures.

8.3.3 Data analysis

The preceding evaluations of the *CVRS models* were conducted in the form of bivariate analyses using *non-parametric ranking procedures* as opposed to *parametric tests.* The use of *non-parametric* procedures was required for two major reasons[3]:

- Firstly, the data available provided insufficient evidence to support the *assumption of normality*
- Secondly, most of the data collected have low orders, because they were measured on *nominal* and *ordinal* scales. Such scales are commonly considered to be unsuitable for parametric testing.

The bivariate analyses have provided information on the significance of associations and group differences between pairs of variables. The levels of the correlations or the group differences indicate the *relative importance* of variables; that is, variables showing high correlations or large group differences can be considered to be more important than variables with low correlations or small group differences.

However, the relationships and group differences suggested in the *CVRS models* are multivariate in nature; that is, individual variables are expected to be related to one or more other variables in the research models. This characteristic of the models suggests that ideally the bivariate analyses should be complemented by further multivariate analyses.

Generally speaking, the strength of multivariate data analyses consists of the simultaneous evaluation of several variables, thus taking account of the inter-correlations of variables. As a result, the *relative importance* of variables indicated in multivariate analyses can differ from that indicated by bivariate analyses. For instance, independent variables, which in bivariate analyses are insignificantly associated with one or several dependent variables, may be shown to be significant in multivariate analyses.

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3 See Section 5.2.2, pp. 131-132.

8.4 Potential of multivariate data analysis

With a view to the use and further development of the *CVRS models* by future researchers this section will demonstrate the potential of multivariate analyses in four selected areas.

It is important to note that, due to the limitations of the data available in this study, the findings obtained from parametric or multivariate procedures do not allow for their generalisation towards the underlying total populations. Hence, the results obtained are indicative as opposed to firm evidence.

8.4.1 Statistical techniques applied

The multivariate statistical procedures used are *multiple regression analysis* and *discriminant function analysis*. The following paragraphs will briefly outline the basics of the procedures together with some other important issues related to multivariate analyses. The main sources of reference used are the statistical textbooks of Bortz [1993], Newbold [1991] as well as Tabachnick and Fidell [1989][4] which may be consulted for further detail as appropriate.

Multiple regression analysis

Multiple regression analysis is a technique which allows one to evaluate the relationship between one dependent variable and several independent variables. The goal of regression is to arrive at an equation that represents the best prediction of a dependent variable from several independent variables. The equation has the following general form:

$$y = a + b_1x_1 + b_2x_2 + \ldots + b_kx_k$$

with y = dependent variable
x_i = independent variable
a = constant
b_i = regression coefficient (unstandardised)

[4] Further discussion of multivariate procedures can be found in McDaniel and Gates, 1991; Backhaus et al, 1987; Katzmier and Pohl, 1984 and Zeller and Carmines, 1978.

There are two key statistics derived from regression analysis:

- ***Regression coefficient*** **(b)**: This coefficient indicates how much a single independent variable in the context of other independent variables contributes to the prediction or the explanation of the variance of the dependent variable.

  The raw b-values of the regression function, which are dependent on the unit of measurement, are commonly referred to as *unstandardised* regression coefficients (b). To be able to compare the coefficients and thus assess the relative importance of the corresponding variables, it is necessary to calculate the *standardised* regression coefficients (b'). "The relative importance of the independent variables can then be determined because all of the variables have identical variances; the variance of each variable is equal to one" [Zeller and Carmines, 1974, p. 167; see also Bortz, 1993 as well as Tabachnick and Fidell, 1989].

- ***Multiple correlation coefficient*** **(R)**: This is the *Pearson product moment correlation coefficient* between the obtained and the predicted values of the dependent variable. The squared multiple coefficient (R^2) indicates the proportion of joint variance between the independent variables and the dependent variable. Thus R^2 denotes the proportion of the variance of the dependent variable which can be explained jointly by the independent variables.

The following analyses are carried out by a *stepwise* or *setwise* version of *multiple regression* used in a "forward" mode. This procedure avoids the unfavourable effects (concerning the interpretation of the b-values) arising from the inter-correlation of independent variables (*multicollinearity*). The procedure has the following basic structure:

- The first independent variable to enter the regression equation is that one showing the highest bivariate (listwise) correlation with the dependent variable. Subsequent independent variables enter into the equation only if, in the presence of other independent variables already in the equation, they make a significant[5] additional contribution to explaining the variance of the dependent variable. Hence, those independent variables affected by *multicollinearity* in relation to independent variables in the equation become "redundant" and are, therefore, prevented from entering into the equation.

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[5] The significance levels required for variables entering the regression equation are the 1%, 5% or 10% level; see Section 5.2.1, p. 130.

- Care must be taken in the interpretation of the results if these are subject to *multicollinearity*. Variables which failed to enter into the regression equation because of *multicollinearity* appear to be unimportant, when they actually are highly correlated with the independent variables already entered into the equation. To be able to evaluate the effects of *multicollinearity* "both the full correlation and the unique contribution of the independent variable need to be considered in interpretation" [Tabachnick and Fidell, 1989, p. 143].

Discriminant function analysis

The main purpose of this technique is to arrive at a function composed of a linear combination of one or more independent variables in order to <u>predict group membership</u> or <u>achieve a maximum difference between groups</u>.

The (unstandardised) discriminant function equation, like the *multiple regression* equation, includes a *constant* and a *discriminant function coefficient* for each variable in the equation. It is common to interpret the relative importance of independent variables on the basis of their associated *<u>standardised</u> discriminant function coefficients* rather than the raw or *unstandardised* values. Variables with *standardised coefficients* loading positively or negatively high make particularly strong relative contributions to predicting group membership.

The problems with *multicollinearity* and the procedures for coping with these are also similar to those in *multiple regression.* Therefore, a step-wise version of *discriminant function analysis* is used in this research. The contribution of independent variables to the prediction of group membership is assessed as they enter the equation. The significance of the improved prediction gained by adding independent variables is evaluated by the *McNeamar's chi square test* (also known as the *McNeamar's test for significance of change*).

Missing values

Missing data in multivariate analyses lead to distortions of the samples and therefore can negatively affect the validity of the results obtained. For instance, a missing value on a single variable pertaining to a case (unit of analysis or respondent) leads to the deletion of all other variables of the same case. Consequently, some method of estimating is needed to retain the cases in the analysis [Tabachnik and Fidell, 1989; Backhaus et al, 1987].

In the current analyses missing data have been replaced by means. "Part of the attraction of this procedure is that it is conservative; the mean for the distribution as a whole does not change and the researcher is not required to guess at missing data" [Tabachnik and Fidell, 1989, p. 64]. Following Tabachnik and Fidell there are three major reasons which justify this procedure for the particular data available in this study:

- Firstly, the proportion of missing data is relatively small.
- Secondly, the missing data appear to be scattered randomly through the data matrix and no evidence was found to assume any bias involved in non-responses.
- Thirdly, the analyses with data subject to replacements were repeated with the original data set with missing values. In most cases the results were similar. If differences were found, the reasons for the change were investigated to "evaluate which result more nearly approximates 'reality'" [Tabachnik and Fidell, 1989, p. 66].

Formation of indices

Some variables in the *CVRS models* (e.g. **drivers' union** and **drivers' performance** concepts) are composed of several dimensions. As these dimensions correlate highly their inclusion in multivariate test procedures would entail the problems of *multicollinearity*. To avoid these problems, the dimensions are merged to form *overall indices* as appropriate. The validity of this procedure is evaluated by *factor analysis, correlation of items with total scores* and the calculation of the *Cronbach Alpha coefficient.*

8.4.2 Scope of analysis

The potential of multivariate data analysis will be demonstrated in four areas of the *CVRS models* which are organised according to the two statistical procedures used:

Regression analysis

- variables predicting **organisations' CVRS awareness** (*hypotheses 4a - 4b*); and
- variables predicting **CVRS operators' performance** (*hypotheses 11a - 11f*).

Discriminant function analysis

- variables discriminating between **CVRS users** and **CVRS non-users** (*hypotheses 3a - 3d*); and
- variables discriminating between organisations where CVRS led to transport cost savings and those where CVRS failed to do so (**organisational efficiency**), (*hypotheses 8b - 8c*).

8.4.3 Multivariate analysis of the CVRS adoption model

8.4.3.1 Multiple regression analysis of *organisations' CVRS awareness*

This *multiple regression analysis* concerns the simultaneous evaluation of variables pertaining to *hypotheses 4a - 4b*.

Hypotheses 4a - 4b: The awareness of CVRS technology is positively associated with the potential users':

- company size (*hypothesis 4a*); and
- centralisation of the data processing or equivalent service function (*hypothesis 4b*).

Multiple regression can only consider one *dependent variable* at a time. Therefore, organisations' awareness of CVRS is measured by the **actual CVRS awareness** variable (indicator: P-191). As this variable is measured independently, it is given priority over the self-reported and, thus, subjectively measured **perceived CVRS awareness** variable[6].

The results of the *stepwise multiple regression analysis* are displayed in Table 8.1[7]. In bivariate analysis both **company size** and **data processing** correlate significantly with **actual CVRS awareness** (see Table 8.2). In the multiple regression, however, only the **company size** variable enters the regression function. With 33% its potential to explain the variance (R^2 adjusted) is relatively high for a single variable. In contrast, **data**

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6 See Section 6.3.3, pp. 155-158.

7 For further detail see Table A2-13 (Appendix 2), p. A-33.

processing makes no further significant explanatory contribution, as this variable correlates significantly with **company size**. In other words, **company size** already includes most of the information contained in **data processing** which becomes "redundant" in the regression equation.

Hence, given the limitations of the data available, as discussed previously, **company size** is the most important variable to predict the level of **actual CVRS awareness.**

Independent variable		**Sig-nifi-cance level (%)**	**Standar-dised regression coefficient (b')**	**Unstan-dardised regression coefficient (b)**	**Stan-dard error of b**	**Em-pi-rical value T**
	label					
INTERCEPT				-0.95	1.97	-0.48
Company size	Q-190a to Q-190d	**1**	**0.59**	3.94	0.84	-4.72
"Redundant" variables:						
Data processing	R-191	ns				
Dependent variable: Actual CVRS awareness	P-191					
Coefficient of determination (R^2)	0.35					
Adjusted coefficient of determination	0.33					

Table 8.1: Multiple regression of *actual CVRS awareness*

Dependent variable	**Independent variable**	**Bivariate results**		**Multivariate results**	
		RCC	**p (%)**	**b'**	**p (%)**
+ Actual CVRS awareness	Company size	0.50	**1**	0.59	**1**
+ Actual CVRS awareness	Data centralisation	0.38	**1**	#	ns
# = variable not entered into the multiple regression equation					

Table 8.2: Comparison of bi- and multivariate results for *hypotheses 4a* and *4b*

8.4.3.2 Discriminant function analysis of *CVRS adoption*

This *discriminant function analysis* concerns the simultaneous evaluation of variables pertaining to *hypotheses 3a - 3d.*

Hypotheses 3a - 3d: The adoption of CVRS technology is positively associated with the potential users':

- awareness of the software available (*hypothesis 3a*);
- pre-attitude towards the software (*hypothesis 3b*);
- industrial relations (*hypothesis 3c*); and
- organisation of decision-making authority for IT in transport (*hypothesis 3d*).

The analysis considers the independently measured and, thus more meaningful, **actual CVRS awareness** variable (indicator: P-191) as opposed to the self-reported **perceived CVRS** variable (indicator: B1 - B3)[8].

The dimensions of the **drivers' union** concept[9] correlate highly and, therefore, enter into an *overall index*. This minimises the number of variables to be considered in the analysis and avoids the unfavourable effects of *multicollinearity*. *Reliability* or *internal consistency* of the index is emphasised by a *Cronbach Alpha coefficient* of 0.86 which is above the minimum level of 0.8. *Construct validity* of the index measure is emphasised by *factor loadings* of 0.96 and 0.98. Further support is given by the overall *total score correlations* of between 0.73 and 0.85.

The **staff's union** concept was omitted from the analysis, because of an excessive proportion of missing responses. The option of replacing missing values with average scores was considered to be inadequate.

The dependent grouping variable is represented by the following two groups[10]:

- Organisations using CVRS and organisations planning to use CVRS in the near future ("*current + future CVRS users*"); and

- Organisations not using CVRS and not planning to use CVRS in the near future ("*current + future CVRS non-users*").

The results of the *discriminant function analysis* are displayed in subsequent Table 8.3. Given the limitations of the data available as outlined previously, the results suggest that

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8 See Section 8.4.3.1, p. 275.

9 See Table 6.4, p. 151.

10 See Section 6.3.2 ("Data analysis"), p. 154-155.

actual CVRS awareness is the most suitable variable to separate *current and future CVRS users* from the *current and future CVRS non-users*. The variable's power to predict group membership is considered to be very good. In fact, the established discriminant function allocates 30 out of 37 cases to the correct group.

Independent variable	Label	Standardised discriminant coefficient (b')	Unstandardised discriminant coefficient (b)
INTERCEPT			-1.37
Actual awareness of CVRS	P-191	**1**	0.17
Excluded variables:			
Pre-attitude towards CVRS	C-10xm		
Drivers' union	D-15x		
Centralisation of decision-making	E-23x		
Involvement of data-processing department	E-24		
Dependent grouping variable: *Current and future CVRS users* versus *current and future CVRS non-users*			
Group centroids (means):			
Current and future CVRS users		**1.06**	
Current and future CVRS non-users		**-0.90**	
Classification of results		**Actual membership**	**Correctly predicted membership**
Number of current and future CVRS users		**20 (100%)**	**19 (95%)**
Number of current and future CVRS non-users		**17 (100%)**	**11 (65%)**
Number of discriminant functions		1	
Significance level (in %)		1	

Table 8.3: Discriminant function analysis of *CVRS users* versus *CVRS non-users*

The addition of the **CVRS pre-attitude** variable improves the classification by a further two cases (7%); that is, both **actual CVRS awareness** and **CVRS pre-attitude** combined predict 32 out of 37 cases correctly. Also, the separation of the groups centroids improves from -0.9 and 1.06 to -1.01 and 1.23 respectively[11].

Despite this improvement in classification of nearly 7%, the *McNeamar's x^2 test for significance of change* indicates that the improvement is not significant. However, because of the small number of frequencies considered in this test, its findings have only

[11] The standardised discriminant function coefficients for both variables are 0.84 (**actual CVRS awareness**) and 0.48 (**CVRS pre-attitude**).

limited validity for the present data scenario [Bortz, 1993]. If the sample were larger, the improvement of 7% might be indicated as significant by this test. Nevertheless, given the lack of evidence for the significance of **CVRS pre-attitude** on the basis of the data available, the contribution of this variable to the prediction of group membership in multivariate analyses is considered conservatively to be non-significant.

It should be noted that **CVRS pre-attitude** taken individually is the second best predictor of groups membership. It classifies 26 out of 37 cases correctly and generates group centroids of -0.55 and 0.65. The variable contributes relatively little to predicting group membership in the presence of the **actual CVRS awareness** variable, because both independent variables correlate significantly at the 1% level. Hence, **CVRS pre-attitude** becomes "redundant" and appears to be of low relative importance in multivariate analysis, despite its high relative importance in bivariate analysis (see Table 8.4).

The inclusion of further independent variables to the *discriminant function analysis* equation does not further improve classification of the cases.

Dependent variable	**Independent variable**	**Bivariate results**			**Multivariate results**	
		CVRS use Rank	**CVRS non use Rank**	**p (%)**	**b'**	**p (%)**
CVRS use / CVRS non use	Actual awareness of CVRS	27.3	12.0	**1**	1	**1**
CVRS use / CVRS non use	Pre-attitude towards CVRS	24.7	14.2	**1**	#	ns
CVRS use / CVRS non use	Drivers' union's project support	14.5	16.4	ns		
CVRS use / CVRS non use	Drivers' non-work-based union representative's support	7.6	9.8	ns	#*	ns
CVRS use / CVRS non use	Drivers' shop steward's support	15.1	15.9	ns		
CVRS use / CVRS non use	Centralisation of decision making	19.91	18.23	ns	#	ns
CVRS use / CVRS non use	Involvement of data-processing department	14.91	16.18	ns	#	ns

*The dimensions of the **drivers' union** concept were merged to an index
= variable not entered into the discriminant function analysis equation

Table 8.4: Comparison of bi- and multivariate results for *hypotheses 3a* to *3d*

8.4.4 Multivariate analysis of the CVRS success model

8.4.4.1 Multiple regression analysis of *CVRS operators' performance*

This *multiple regression analysis* concerns the simultaneous evaluation of variables pertaining to *hypotheses 11a - 11f.* Due to the problems involved in the operationalisation of the **CVRS system quality** variable (*hypothesis 11g*), the latter is not considered in the analysis[12].

***Hypotheses 11a - 11f*:** The CVRS operators' performance is positively associated with their: • CVRS satisfaction (*hypothesis 11a*); • specialised training on the software - "CVRS training" (*hypothesis 11b*); • educational (college/in-house) computer training (*hypothesis 11c*); • school education (*hypothesis 11d*); • computer literacy (*hypothesis 11e*); and • work experience in VRS (*hypothesis 11f*).

The results of the *stepwise multiple regression analysis* are displayed in following Table 8.5[13]. The multivariate findings are consistent with those obtained from bivariate analysis (see Table 8.6)[14]. The results suggest that **schedulers' CVRS satisfaction** is the best predictor for **CVRS operators' performance**. Further significant predictive power is provided by **CVRS training.**

The two variables combined explain a relatively small proportion of the total variance (adjusted $R^2 = 0.12$ or 12%). With respect to **CVRS operators' performance**, the *CVRS success model* apparently is not fully complete. Some further relevant variables are likely to be found in the field of **individual differences**. This study has only looked at a small number of potential variables in this field. Other variables of particular interest are expected to relate to cognitive styles and personality traits. A further potentially important variable may be **CVRS system quality** in terms of the complexity and user friendliness of CVRS technology. This variable is part of the model, but, due to the

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12 See Sections 6.5.2 (pp. 176-177), 7.3.1 (pp. 218-219) and 7.3.3 (pp. 224-235).

13 For further detail see Table A2-13 (Appendix 2), p. A-32.

14 See also Section 7.5.3, pp. 247-248.

aforementioned methodological and operational problems, was not considered in the analyses.

Independent variable	Label	Significance level (%)	Standardised regression coefficient (b')	Unstandardised regression coefficient (b)	Standard error of b	Empirical value T
INTERCEPT				3.85	0.65	5.92
Schedulers' CVRS satisfaction	H-1s	**5**	**0.29**	0.24	0.11	2.28
CVRS training	L-98x	**5**	**0.25**	0.14	0.07	2.02
Excluded variables:						
Educational computer training	M-58	ns				
School qualification	T-195x	ns				
Computer literacy	M-57x	ns				
Experience in VRS	U-164	ns				
Dependent variable:						
CVRS operators' performance	J-156x					
Coefficient of determination (R^2)	0.15					
Adjusted coefficient of determination	0.12					

Table 8.5: Multiple regression of *CVRS operators' performance*

Dependent variable	Independent variable	Bivariate results		Multivariate results	
		RCC	p (%)	b'	p (%)
CVRS operators' performance	Schedulers' CVRS satisfaction	0.30	**5**	0.29	**5**
CVRS operators' performance	CVRS training	0.24	**10**	0.25	**5**
CVRS operators' performance	Educational computer training	0.24	**10**	#	ns
CVRS operators' performance	School education	0.04	ns	#	ns
CVRS operators' performance	Computer literacy	0.15	ns	#	ns
CVRS operators' performance	VRS work experience	0.08	ns	#	ns

\# = variable not entered into the multiple regression equation

Table 8.6: Comparison of bi- and multivariate results for *hypotheses 11a* to *11f*

8.4.4.2 Discriminant function analysis of *organisational efficiency*

This *discriminant function analysis* concerns the simultaneous evaluation of variables pertaining to *hypotheses 8b - 8c*. Again, due to the problems involved in the operationalisation of the **CVRS system quality** variable (*hypothesis 8a*), the latter is not considered in the analysis[15].

> ***Hypotheses 8b - 8c***: Organisational efficiency of CVRS users is positively associated with the:
>
> - CVRS operators' performance (*hypothesis 8b*); and
> - Drivers' performance (*hypothesis 8c*).

The dimensions of the **drivers' performance** concept[16] are combined to an *overall index*. *Reliability* or *internal consistency* of the index is emphasised by a *Cronbach Alpha coefficient* of 0.86 which is above the minimum level of 0.8. *Construct validity* of the index measure is emphasised by *factor loadings* of 0.95 and a high *total score correlation* of 0.74.

It should be noted that the **drivers' performance** is a behavioural as opposed to a cognitive variable (a variable concerning mental states). The measurement of this variable by the managers and the schedulers on behalf of the drivers is considered to be a valid procedure as discussed earlier[17].

Organisational efficiency is described by the (dependent) grouping variable including the categories:

- Operational distribution sites where CVRS saved transport cost; and
- Operational distribution sites where CVRS failed to save transport cost.

The results of the *discriminant function analysis* are displayed in Table 8.7. The results propose **drivers' performance** as the most suitable discriminator to separate operational distribution sites managing to reduce transport costs from those sites where this was not achieved. The established *discriminant analysis function* allocates 27 out of 38 respondents to the correct group. Thus, the variable's power to predict group membership can be considered to be good.

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15 See Sections 7.3.1(pp. 218-219) and 7.3.3 (pp. 224-235).

16 See Table 7.17, p. 221.

17 See Section 1.4.1.2, pp. 21-22.

The inclusion of the **CVRS operators' performance** variable in the discriminant function makes no further contribution to improving the classification of the cases and, thus, predicting group membership more accurately. These findings are consistent with the previous bivariate findings[18] (see Table 8.8).

Independent variable		Standardised discriminant coefficient (b')	Unstandardised discriminant coefficient (b)
	Label		
INTERCEPT			4.09
Drivers' performance	K117d +K178d	1	0.85

Excluded variables:			
Operators' performance	J-156x		
Dependent grouping variable: Organisational efficiency (*transport cost savings* versus *no transport cost savings)*			
Group centroids (means):			
Sites with transport cost savings		**0.20**	
Sites without transport cost savings		**- 0.73**	
Classification of results		**Actual membership**	**Correctly predicted membership**
Sites with transport cost savings		**8 (100%)**	**4 (50%)**
Sites without transport cost savings		**30 (100%)**	**23 (77%)**
Number of discriminant functions		1	
Significance level (in %)		5	

Table 8.7: Discriminant function analysis of *organisational efficiency*

Dependent variable	Independent variable	Bivariate results			Multivariate results	
		Saving yes	Saving no	p (%)	b'	p (%)
		Rank	Rank			
Transport cost savings yes/no	Drivers' performance A	19.9	11.6	**10**	1*	**1***
Transport cost savings yes/no	Drivers' performance B	20.0	10.8	**5**		
Transport cost savings yes/no	CVRS operators' performance	24.7	26.0	ns	#	ns

*The dimensions of the drivers' performance were merged to an index
= variable not entered into the discriminant function analysis equation

Table 8.8: Comparison of bi- and multivariate results for *hypotheses 8b* and *8c*

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18 See Table 7.20, p. 224.

8.4.5 Overview of main empirical findings

Following Figure 8.1 shows the bivariate findings from the previous two chapters complemented by the multivariate results generated in this Chapter. The bivariate relationships found significant and non-significant are indicated by continuous lines and dashed lines respectively. The relationships found significant in the multivariate analyses are super-imposed and can be identified by lines printed in bold.

Note that the relationship between variables and **CVRS system quality** marked with a dotted line has not been tested empirically with survey data in the current study[19].

In interpreting the multivariate results shown in Figure 8.1 it needs to be considered that only four sets of hypotheses (4a to 4b, 11a to 11f, 3a to 3d and 8b to 8c) were tested by multivariate procedures. The other hypotheses were unsuitable for multivariate testing either because they were designed for uni- or bivariate analysis only, or because the data available was inappropriate.

The interpretation of the results also needs to take account of *multicollinearity*. Certain variables subject to *multicollinearity* did not enter into the multivariate equations. As a result, these variables are labelled non-significant despite their actual significance in bivariate analysis.

A further problem is that of *causality*. Statistical testing in non-experimental research essentially does not allow for conclusions of *causality*. As pointed out earlier, Tabachnik and Fidell [1989, p. 127 - 128] suggest: "Demonstration of causality is a logical and experimental rather than statistical problem. An apparent strong relationship between variables could stem from many sources, including the influence of other, currently unmeasured variables."

Finally, it is once again emphasised that the data available in this study fail to comply with certain requirements of multivariate procedures. The deficiencies concern the lack of evidence to support the *assumption of normality* and the fact that most of the measurement scales used in this research are generally unsuitable for parametric testing. Therefore, the above multivariate analyses serve primarily as examples for future researchers to demonstrate their potential within the *CVRS models*. The results can only be treated as indications rather than firm evidence.

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19 See Sections 6.5.2 (pp. 176-177), 7.3.1 (pp. 218-219), 7.3.3 (pp. 224-235) and 7.5.2 (pp. 244).

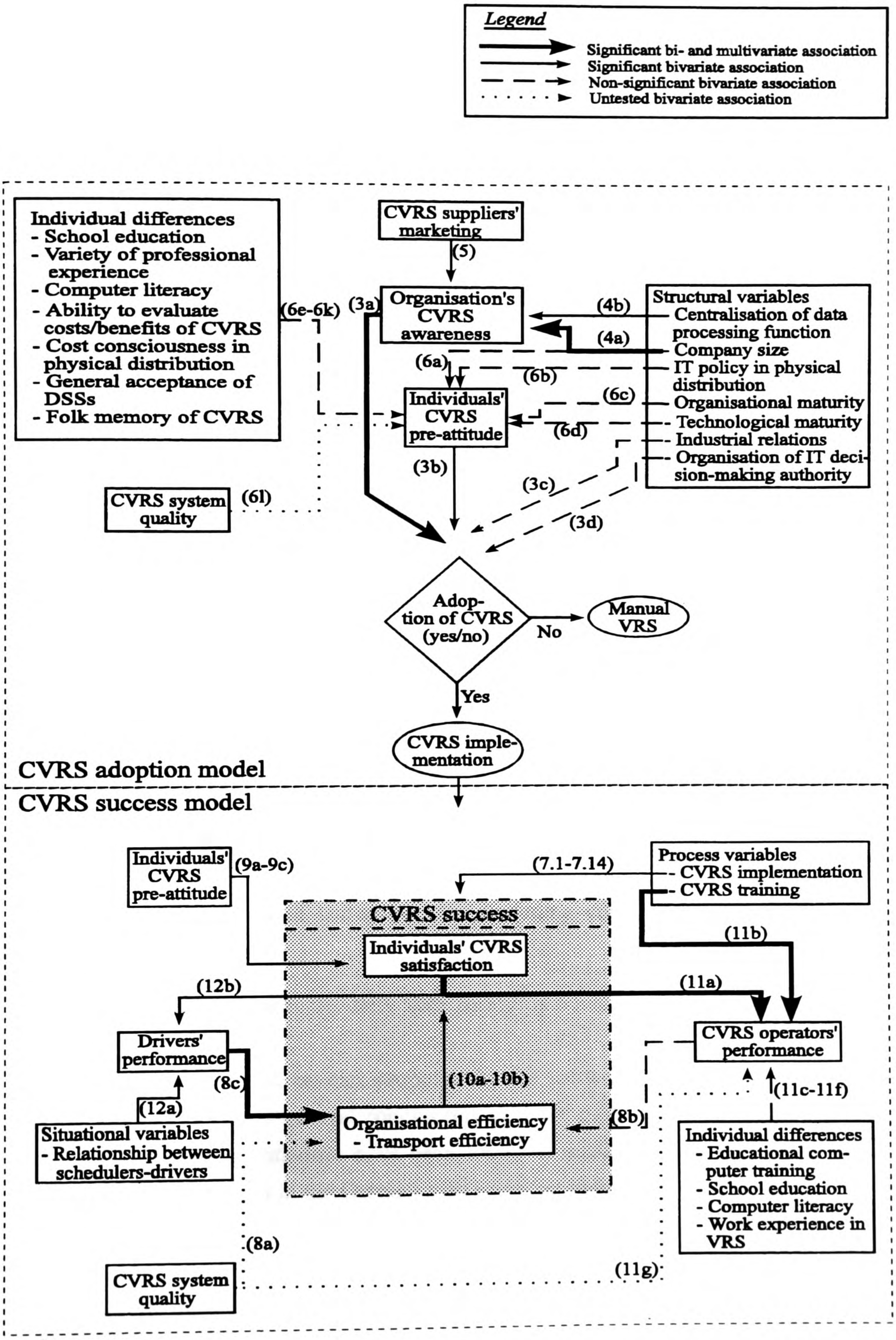

Figure 8.1: Overview of bi- and multivariate findings of the CVRS model in the organisational context

Chapter 9: Conclusions

9.1 Summary of main results

The present research has investigated the use of CVRS technology in road transport with special emphasis on the brewing industry. The empirical research is based on the powerful *triangulation of measurement* approach which combines both qualitative (case study) and quantitative research (survey) methods.

The research focused on three main areas:

CVRS success

The first major research objective has been to investigate the *success* of CVRS technology. The current study provides overwhelming evidence that CVRS technology is successfully used in the brewing industry. Special attention should be paid to two key aspects of success in operational CVRS:

- the average savings of transport costs including costs of vehicles and drivers amount to 9%[1]; and
- the average reduction in the daily VRS period[2] is 6 hours or 56%[3].

These findings confirm the savings proposed by the software suppliers. Moreover, the findings are similar to the general conclusions of many past studies on applied CVRS. The most remarkable similarities have been found in relation to Bargl's [1994] recent study on the use of CVRS in the German road transport industry.

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1 This figure is based on sites from the "second population", these being sites which managed to reduce the vehicle fleet. See Section 3.3.2.2, p. 68.

2 Time required for generating routes for a particular delivery day.

3 This figure is based on sites from the "second population", these being sites which managed to reduce the VRS period. See Section 3.3.2.2, p. 68.

Hence, the positive and significant impact of operational CVRS on transport cost savings can be considered as sufficiently substantiated by both qualitative and quantitative evidence.

Adoption of CVRS technology

The second major research objective has been to investigate the adoption of CVRS technology in Britain's road transport industry as a whole and, in particular, in Britain's brewing industry.

Road transport industry: By comparing the approximately 5,000 potential CVRS users in terms of fleet operators (depots) with the 534 operational distribution planning sites actually using CVRS, the current research suggests an adoption rate of about 11%. This rate is extremely low considering the substantial tangible and intangible benefits which the software can provide.

Britain's brewing industry: Again, the adoption rate of CVRS technology has been determined by a comparison of potential and current users of CVRS. The adoption rate in terms of *independent operating centres* has been found to comprise:

- 35% or 6 current out of 17 potential users of *strategic-tactical* CVRSSs; and
- 27% or 13 current out of 49 potential users of *operational* CVRSSs.

The adoption rate of 27% of operational CVRSSs is significantly higher than the average of only 11% in the total road transport industry. Nevertheless, when comparing the 27% adoption rate with the brewing industry's high adoption of many other distribution software systems such as sales order processing (98%) and stock control (83%) systems the "CVRS user-gap" is also apparent in this sector of road transport.

Factors associated with the adoption and success of CVRS

The third major research objective has been to develop and empirically validate a *CVRS model in the organisational context*; this is a research framework focusing on organisational variables in order to explain the adoption and success of CVRS technology. In both areas of research a number of critical factors were identified. These factors, together with the evidence found from the preceding descriptive research of this study, form the basis of **recommendations** which are presented in the subsequent Section 9.2.

Note that, with respect to the CVRS models, the recommendations are based on findings obtained from the non-parametric analyses. Given the constraints of the data available, the multivariate findings are not considered.

9.2 Recommendations

9.2.1 How to overcome the "CVRS user-gap"

To increase the adoption of CVRS technology, appropriate measures need to focus on the potential users' awareness of and attitude towards the software.

Awareness

The development and introduction of measures to increase the awareness of CVRS needs to be undertaken by both the suppliers and potential users of CVRS. Ideally, action should also be taken by public and private organisations or institutions.

Governmental action to promote the use of CVRS seems appropriate because the technology provides benefits which reach beyond improving the organisational efficiency of individual fleet operators. In fact, CVRS also needs to be viewed as an effective means of improving the utilisation of our road network, of using energy resources more efficiently and, ultimately, limiting environmental damage caused by air pollution.

CVRS suppliers: The suppliers have to boost their marketing activities to more effectively inform potential users of CVRS technology about its availability, and, perhaps more importantly, its full benefits. Given the very nature of CVRS technology, which belongs to the generally less accepted group of DSSs, this marketing effort will need to be substantially stronger than would be required for standard MISs and TPSs, such as fleet information systems and sales order processing systems respectively.

Having regard for the limited financial and human resources of many suppliers, the publication of "features" and case studies on practical CVRS applications in specialised trade journals is perhaps the marketing activity which offers best value for money. The best effect on CVRS may be achieved if such case studies and features are written by independent authors as opposed to the suppliers themselves.

CVRS users: Personnel who decide on the implementation of CVRS often have no or only a limited awareness of CVRS technology. This is particularly the case in small organisations where the data processing function has less formalised structures. Here the decision to implement CVRS is generally made by the local transport or distribution managers. They may have, due to pressure of other managerial duties, insufficient time or even lack the inclination to investigate the availability as well as potential benefits of CVRS technology and stay up-to date with the continuous developments made in this area.

There is obviously a need for more top-management emphasis on providing companies' decision makers with knowledge about CVRS. If human resources and specialised knowledge in the data processing function are limited and therefore do not allow for the provision of internal training, help may be obtained at external events. This may involve regular visits to exhibitions or conferences on IT in distribution. Some CVRS suppliers also offer specialised training courses on their software, usually at reasonable cost.

The cost of such measures seems to be negligible compared with the significant potential benefits which the use of effective CVRSSs can provide.

Private and public organisations/institutions: To the author's knowledge, private and public organisations or institutions have not recently undertaken any major initiatives to promote general awareness about the availability, practical use, costs and benefits of CVRS technology.

Initial steps in the right direction have been events such as the annual *ILDM (IL) exhibition* at the NEC, Birmingham. However, the potential users of CVRS technology want to see practical evidence of the efficiency of the software.

A positive example of such action is the recent study "Tourenplanung"[4] organised by the German transport society **Gesellschaft für Verkehrsbetriebswirtschaft und Logistik (GVB)**. It tested the efficiency of CVRSSs using empirical data collected from different fleet operators.

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[4] Translation: VRS.

A further example is the large scale project "INTAKT (Interaktives Gewerbeinformationssystem" initiated by the German society of freight transport **BDF e.V.**[5] in the late eighties [Eckstein et al, 1988]. The project aimed to promote co-operative development of a central CVRS system amongst commercial fleet operators in the general road haulage sectors. The operators would ultimately pool all their orders and vehicles into the central CVRS system which would generate routes according to strict economic criteria.

CVRS attitude

Perhaps the most significant obstacle in overcoming the "CVRS user-gap" is the attitude of the potential user in relation to both financial as well as technical aspects of the software.

This study fails to explain which factors influence the pre-implementation attitude towards CVRS on the part of individuals who decide on the software's implementation.

However, when tested on the basis of all individuals participating in the current research, significant associations were identified between individuals' pre-implementation attitude towards CVRS and two groups of factors:

- general attitudes about IT; and
- the extent to which a firm emphasises the importance of investing in IT.

These findings highlight the importance of effective and on-going training on issues of information technology. General training needs to ensure that information technology is understood as a major ingredient in offering a competitive advantage and thus the key to future success. Such general measures need to go hand in hand with the development of a positive IT policy or company philosophy which favours the availability and use of IT at all levels of an organisation.

As far as training on the special issues of CVRS is concerned, this needs to explain the general theory behind the software and thus open the "black box". It may be this very "black box" character of CVRS or the lack of understanding of the software's operating principles, which raises people's disbelief in the efficiency of the software.

5 Bundesverband des Deutschen Güterfernverkehrs e.V., 60457 Frankfurt am Main 93; Postfach 93 02 60, Tel.: (069) 79190.

Companies rejecting CVRS appear to blame the software's perceived inefficiency on its inability to cope with certain delivery constraints which are of particular relevance to their individual operations. Also, there seems to be a wide-spread view that CVRS technology should be an automation of the manual VRS technique. If the CVRSS fails to be this, it is considered to be ineffective or non-appropriate for individual requirements. The reality about CVRS, however, is clearly different:

- Firstly, CVRS does not generate routes in exactly the same way as manual VRS.

- Secondly, the standard versions of CVRSSs usually cope with the great majority of individual operators' delivery constraints, but rarely with all of them. If necessary, most suppliers are able, often at additional charges, to customise their system according to the users' individual requirements. But again, this may not necessarily satisfy all of the users' expectations.

  In practice, companies can use CVRS to improve their operating efficiency even if CVRS does not model every constraint of their operations. Also, some factors which the software may be incapable of handling can be allowed for "outside" the CVRSS; that is, the scheduler can make manual adjustments to accommodate factors such as adding late customer orders to already generated routes or allocating drivers to vehicles.

Therefore, if organisations want to make full use of the software's ability to increase transport efficiency they may have to change their attitude and accept that implementing CVRS may require some adaptation of their operating practices. Organisations should also recognise that it is worthwhile using CVRS to improve their efficiency even if the software does not allow for optimum solutions.

9.2.2 Who should use CVRS technology

Assuming a reduction in average transport costs, including costs for vehicles and drivers, of approximately 10% on average, as shown by the evidence provided by this study and past research, the potential user of a CVRSS should run a fleet of 10 vehicles or more. This may be necessary to justify the software's implementation in terms of tangible direct costs savings resulting from a reduction in the vehicle fleet within a time period of one to three years.

However, such a purely "transport cost" oriented view ignores the personnel cost savings achieved from a reduction in the VRS period. These may also be substantial. Hence, CVRS technology may be affordable also for many smaller operators.

The research has empirically evaluated the suitability CVRS for exclusively own-account operators in brewing distribution. Nevertheless, some general conclusions can be drawn as follows:

CVRS has been shown to be successful in organisations involved in secondary retail distribution in the brewing industry which operate in a highly restrictive distribution environment in terms of tight time windows, complex road networks, high customer service expectations etc. Consequently, there is good reason to suggest that CVRS also performs successfully in sectors with equally or less restricted operating environments and similar basic VRS problems; the latter are characterised by *depot-bound* transport operations involving *multiple-drop* deliveries or collections. Such characteristics are common for VRS problems of many sectors of road transport. It is not surprising, therefore, that CVRS is in fact also used in various sectors other than brewing or food and drink[6].

Ideally, but not necessarily, the user of CVRS should have a relatively stable customer base, as this reduces the effort of updating the software's customer data file and allocating customers to the road data base. The latter task needs to be carried out with great care, because accurate and up-to-date data is a precondition for achieving high quality planning results.

9.2.3 Which type of CVRS technology to use

With the exception of the comparative studies reported in Sections 7.3.3 and 7.5.3[7] this research has not investigated the quality of individual CVRSSs in great detail. Therefore, no recommendations will be made on which packages to use. Nevertheless, some general guidelines for the potential buyer can be derived as shown below:

The breweries investigated in the current research all share the same basic VRS problems but use different CVRSSs to solve these. Most of the systems have been reported to

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6 See Figure 4.1, p. 107.

7 See Sections 7.3.3 (pp. 227-235) and 7.5.3 (pp. 248-250).

fulfil their users' expectations and are considered to be successful overall. This situation leads to the general conclusion that the standard VRS problems of breweries can be successfully solved by most of the CVRS packages currently available.

However, the qualitative and quantitative evidence also suggest that CVRS packages differ with respect to the amount of cost savings provided as well as the schedulers' understanding of the software and their ability to operate it. Moreover, there are some indications that CVRS packages perform differently in different operating environments. At its most extreme, a particular CVRS may perform successfully in one operating environment and fail in another.

A key aspect of the quality of CVRS packages appears to be the road data base. A useful measure for the quality of the road data base is the level of road detail (i.e. road nodes and links) and the accuracy with which customers are allocated to the road data base. In both areas the CVRS packages currently available can vary substantially. For further detail see Eibl [1993c].

Some other important quality aspects are

- the effectiveness of the route generation algorithms;
- the level of control over the route generation algorithms;
- the ability to model operational constraints; and
- the suppliers' ability and willingness to customise their products.

Hence, potential users of CVRS should thoroughly test various packages on the basis of their own empirical transport data. Ideally, the software is tested on site over a period of several weeks. Only this will fully reveal which package models an organisation's transport operations most appropriately.

9.2.4 How to ensure CVRS success

Technological and organisational maturity

The potential users of CVRS should operate a computerised sales order processing system from which orders are down-loaded directly into the CVRSS. This method is quick and allows the user to control the number and types of orders to be planned in each VRS session. It also reduces the amount of incorrect data entry caused by human error.

Ideally, the CVRS should also be interfaced with a warehouse software system which generates documents such as lists for order picking and vehicle loading as well as delivery notes.

Despite generally good on-site support provided by the software suppliers and in spite of the availability of telephone help-lines, unexpected technical problems can occur during the software's implementation and subsequent use. In particular the creation of the data transfer interface between a host computer, for example a mainframe computer, and the CVRSS can be difficult and time consuming to implement.

Also, some packages have special planning parameters such as *strategy files*, which are comparable to macros or user-specified sub-routines. These allow the scheduler to control the manner in which the software's algorithms generate routes. *Strategy files* are user-defined and therefore adjustable to individual requirements. Best planning results will be achieved if the user develops his/her own library of *strategy files* which may vary on a daily basis. Since distribution environments are dynamic, strategy files may need continuous adjustment to changing requirements.

To be able to quickly and effectively cope with any technical problem, in particular the generation of computer sub-routines such as *strategy files*, it is useful to have permanent access to in-house expert support provided by personnel who are familiar with both computing and a firm's particular operations in physical distribution.

Appropriate implementation

The study suggests the following general guide-lines for the implementation of CVRS used in an <u>operational</u> role:

- There are many CVRS packages on the market and most may suit a firm's <u>basic</u> requirements. However, the problem will be to identify the system (as well as associated expertise and back-up support by the supplier) that best meets a firm's needs. Several packages should be evaluated, ideally in-house, or, alternatively, by the software supplier using the firm's distribution data.. This can be a lengthy process taking up to several months.

However, compared with the substantial savings which the software can provide, the effort is likely to pay off fairly quickly. For instance, an operator with a fleet of 20 vehicles may save an additional vehicle if he manages to identify a package which reduces transport costs by say 5% more than a rival package. Similarly, a CVRSS which reduces the daily VRS period by two hours more than a rival system is able to achieve, may save extra personnel costs of £2,000 per year for each scheduler.

- The implementation of the first CVRS package can be expected to take approximately 16 full-time man weeks. Therefore, careful and timely planning is extremely important. Any unnecessary delays may lead to a loss of enthusiasm among key personnel and thus endanger the project's success.

- Due to the cross-functional character of VRS, the implementation of CVRS will cause change for many individuals within an organisation. As people generally dislike change, they will frequently try to resist it, as it may be perceived as a disruption of their familiar work routines. For instance, the schedulers may regard the fact that CVRS produces better routes than they are able to achieve manually as a criticism of their own performance. At the most extreme, CVRS is viewed as a threat to job security.

  Management needs to overview the total process of change, ensuring that any such concerns are dealt with properly. The process of change will require strong support from top-management acting as a model for the development of positive attitudes and implementation behaviour amongst the personnel involved. If management fails to act this way, the implementation is put at risk.

- The responsibilities for the total implementation from its beginning to its end including the post-implementation stage need to be centralised in the hands of one or, at most, a few people. There is nothing worse than the situation where the person who initiated the implementation leaves the company or is promoted to another position mid-way through the project.

  In large organisations with several depots, the change from manual VRS to CVRS may be facilitated by appointing a *system steering group*. The group should be composed of experts with special knowledge in matters of data processing and a firm's operations in physical distribution. The system steering group organises, guides and overviews the implementation process at both the strategic and operational level.

An important ingredient of the system steering group appears to be the availability of a project leader with decision-making authority. This will allow the project to cope with any friction occurring between individuals in the same or different parts of an organisation. Again, this may avoid unnecessary delays which are detrimental to the implementation success.

- "Planning" the development of individuals' conviction about the success of and commitment to the project, will help to quickly overcome most implementation problems and thus keep up the necessary momentum of change. "Planning" here means that management should identify and involve key people who have the potential to motivate others. These may be formal or, perhaps more effectively, informal group leaders.

- The progress made during the implementation and the subsequent use of the software needs to be evaluated at regular intervals. The system operators may acquire certain operating patterns which make their life easy, but do not necessarily maximise transport cost efficiency. A useful way of evaluating the operators' performance may be to regularly compare readily available key ratios such as average orders or mileage per route and time interval etc.

- Once the software is running live, the effort of accurate data handling and validation still has to continue. This involves continuous updating of distribution data and the software's parameters according to changes in the distribution environment and in the company's needs.

  If the CVRSSs used operate on the basis of sub-routines or *strategy files* the updating procedures can require specialised knowledge in computing and should therefore not be left to the system operators alone. The system operators should be assisted by expert knowledge available within the organisation and/or from the software's suppliers.

User satisfaction

Just as positive attitudes and behaviour help to assure the successful <u>implementation</u> of the software, satisfaction with CVRS is a key ingredient in the successful <u>operation</u> of the software.

One way of improving users' satisfaction with the software appears to be ensuring that they have positive pre-implementation attitudes towards the software. People who do not believe in the software in the first place, will not contribute a great deal to make the software work successfully. Instead, they are likely to be keen on raising practical objections whenever there is an opportunity to do so. Such opportunities are bound to arise. In contrast, people with positive attitudes will have the inclination to tackle any problem which occurs and, even if a problem cannot be solved, they will accept this in view of the overall benefits.

CVRS operators

CVRS systems vary in terms of quality of their user interfaces which appear to affect the schedulers' understanding of and ability to operate the software. Most of today's software packages such as word processing systems or spread-sheet systems run in Windows environments, because these types of interfaces are commonly accepted as being user-friendly and effective. Similarly, this study suggests that Windows-based CVRS packages are user-friendly, thus, offering the potential to increase the users' performance levels. The quality of the user interface will be of particular benefit for day-to-day operations at the depot level, where permanent time pressure forces schedulers to make decisions quickly. Consequently, one way of enhancing the performance levels of the system operators is to select CVRS packages with effective user interfaces.

The user interface may also need customisation, which may incur extra costs. However, if this allows for enhancing the schedulers' understanding of and ability to operate the software, the costs of customisation may well pay off.

CVRS technology is a complex technology. Management has to ensure that the CVRS operators receive adequate training on the software. The level of training required can vary significantly from one scheduler to another, depending on their initial level of computer literacy.

Hence, it may not be sufficient to simply introduce the schedulers to the basics of the software, hoping that they will acquire the necessary detailed knowledge when working on the job. As a matter of fact, the work pressure and the hectic nature of daily operations often give schedulers little opportunity to explore the software's full potential.

Also, there is a danger inherent in training a scheduler by personnel who themselves do not fully understand the package. A typical example is where a poorly-trained CVRS operator introduces the software to a new scheduler who then is expected to either assist or replace the CVRS operator.

There is good reason to believe that the schedulers' ability to operate the software determines the level of transport cost savings, although there is no quantitative evidence for this from the current research. This lack of evidence may be explained by the fact that the samples used are relatively small.

Providing specialised and, perhaps most importantly, extensive training on the CVRS software may cost several thousand pounds. Assuming that the expected relationship between the schedulers' understanding of the software and transport cost savings does hold, then the costs of training are likely to be largely outweighed by the benefits which training will provide.

Considering the great importance of the schedulers' work, organisations may need to reappraise the schedulers' positions within the organisation. With an average annual income of around £10,000 this job appears to be underpaid. Perhaps companies need to upgrade the scheduler's work and remunerate it according to its true value and responsibility. This would lead to a general rise in the requirement profile of the future scheduler and also increase management's perception of the need for adequate training of the scheduler. Ultimately this may ensure that the CVRS operators use the software at its full potential.

Drivers

The availability of effective routes generated by a good CVRS package and a good CVRS operator will lead to an increase in transport efficiency only if the drivers are willing and able to adhere to the routes proposed.

The people best able to influence the drivers' willingness to adhere to the proposed routes are likely to be those standing closest to the drivers at both a personal and professional level. These people tend to be the schedulers. Hence, developing a good relationship between the schedulers and the drivers can help to bridge the gap between potential transport cost savings and the transport cost savings actually achieved.

9.2.5 How to evaluate CVRS success

The potential user of CVRS needs to evaluate the success or benefits of CVRS on the basis of a multi-dimensional measure. Such a measure has been developed and empirically validated in this study. It evaluates CVRS success in terms of

- the *macro level*, covering tangible and intangible aspects of organisational efficiency; and
- the *micro level*, concerning issues of user satisfaction.

Special focus needs to be placed on the software's intangible benefits such as enhanced customer service and cost control. The fact that these benefits are *intangible* does not make them less important than the *tangible* ones. On the contrary, they may have significant financial implications which ultimately outweigh the tangible benefits.

The implications of CVRS also need to be seen in the context of logistics as a *total system* and the *order cycle* which comprise the three basic logistical sub-systems and the operational areas of physical distribution respectively.

Any view of CVRS success which considers tangible or "hard" benefits only will fail to supply a realistic evaluation of the software's full benefits.

9.3 Limitations of the current research and suggestions for future research

9.3.1 CVRS research in general

Empirical research on management aspects of CVRS technology is generally constrained by the small number of organisations using the software. This limitation is compounded by both the difficulty in identifying those organisations and the problem of gaining their co-operation over long periods. The latter problem in particular applies to highly competitive industries such as the British brewing industry. Here the personnel work under constant time pressure and company policy tends to heavily restrict the disclosure of business information. These factors are probably some of the main reasons why past research was pre-occupied with the computational and technical rather than the managerial side of CVRS.

There clearly is a need for future research to give more attention to managerial aspects of CVRS technology. The perhaps most important aspects concerning the adoption and success of CVRS technology have been addressed by the present study. Future research may extend the present findings by investigating some of the research aspects covered in further detail, or investigate new management aspect of CVRS technology not covered so far. Some research questions addressing new managerial aspects of CVRS are presented below:

- How do business cultures affect the way in which organisations select CVRS technology? In other words, do organisations with highly specialised staff and high levels of organisational maturity select CVRS packages by criteria which are different to those applied by organisations with opposite characteristics?

- Can organisations be classified into certain types of CVRS buyers, for example, buyers of **high-technology CVRS systems**, **standard CVRS systems** or **best value for money CVRS systems**?

- Do CVRS packages with integrated (usually digitised) road databases perform better in transport operations than CVRS packages using techniques based on Euclidean (air-line) distances in conjunction with correction factors to simulate actual road distances? If this the case, how high is the improvement and are there differences in improvement with respect to particular types of VRS problems and distribution areas?

- What are the practical benefits of using computer graphics in CVRS packages showing customer locations and routes on the underlying road network?

- What are the costs and benefits of using CVRS technology in combination with on-board computers or satellite vehicle-tracking facilities (Geographical Positioning Systems - GPS).

- What are the costs, benefits and problems of using CVRS for simultaneous multiple depot planning?

9.3.2 CVRS models

The primary limitations of the current research and suggestions for future research concern the two *CVRS models* presented in Chapters 6 to 7. A detailed discussion of these limitations and suggestions has been presented in Chapter 8[8].

9.3.3 CVRS success

For methodological, practical and financial reasons this research has investigated the costs and benefits of CVRS in relation to a single sector of road transport as opposed to the road freight industry as a whole. The British brewing industry was selected as the most appropriate field of research, because of its small size, suitable basic VRS problem and the relatively large number of CVRS users.

Consequently, the findings concerning the costs and benefits of CVRS technology essentially relate to the brewing industry only. On the other hand, it has been argued that the general findings of this study may also be related to sectors of road transport with equally or less restricted operating environments and similar basic VRS problems. Strong support for this assumption is provided by the consistency of some of this study's key findings with the findings of Bargl's [1994] recent empirical research on CVRS in the German road freight industry.

To further substantiate the assumption that CVRS is generally successful for fleets of at least 10 vehicles involved in *depot-bound* multiple delivery or collection operations, future research may investigate CVRS success in sectors other than the brewing industry. The present study provides a readily available measure of **CVRS success**. The measure is general enough to be applicable to most sectors of road transport, but it may need modification or adoption to meet particular requirements as appropriate.

Future empirical research may also investigate the suitability of using CVRS technology for specialised VRS problems. Examples are the VRS problem of road tankers or the typical *general haulier* VRS problem[9], involving a combination of delivery and collection operations.

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8 See Section 8.3, p. 262f.

9 See Section 2.5, p. 44.

9.3.4 CVRS adoption

The adoption of CVRS technology has been investigated for the total UK transport industry and, separately, for the British brewing industry.

The figures relating to the adoption of CVRS by own-account operators involved in brewery distribution are considered to be fully reliable, because the total industry has been investigated in great detail. The data used were entirely self-collected and no assumptions were made.

In contrast, the figures regarding the adoption of CVRS in the total road transport industry are based on data provided by the software suppliers and the Department of Transport (HMSO). The following limitations need to be considered:

- The data provided by the software houses have not been verified. Therefore, the possibility of inaccurate data cannot be excluded. However, due to the extremely good relationship between the author of this research and the software houses involved, deliberate provision of inaccurate data is unlikely.

- The HMSO statistic used to determine the number of potential CVRS users dates back to 1987. On the basis of certain assumptions the raw data of this statistic were transformed to indicate the number of vehicle fleets by fleet size (e.g. fleets with one vehicle, two to five vehicles etc.). Subsequently, the number of vehicle fleets identified from this statistic (indicating approximately 7,400 fleets with more than 10 vehicles) was reduced conservatively by an estimated one third, taking account of two factors: firstly, the proportion of vehicle fleets used exclusively for single or trunking transport operations, and secondly, the possible decrease in the number of vehicle fleets between the period covered by the HMSO statistic in 1987 and the time of the current study.

Due to the above limitations, the numbers of potential and actual CVRS users identified in this research cannot be considered completely accurate. However, with respect to the great care applied in the collection of the data and the fact that the assumptions made are generally conservative, the results obtained can be considered as the best estimates available at the present time.

Future research, ideally in the form of large-scale projects organised by institutes or associations with sufficient human and financial resources, may re-investigate the adoption of CVRS technology in the total road transport industry. Due to the small number of CVRS users overall, the sample used in such a market survey will be very large. Therefore, special care will be required to ensure proper selection of the sample. In the case of non-response, which is bound to occur, the problem of bias needs to be investigated in detail.

It is recommended that the proposed concept of *independent operating centres with CVRS decision-making authority* should be considered. These centres can be individual organisations or parts of organisations with their own decision-making body responsible for the acquisition or implementation of CVRS technology and distribution software in general[10]. Measuring the adoption of CVRS technology in terms of such *independent operating centres* is considered to be more appropriate than in terms of *organisations* as such.

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[10] See Section 4.2.3, p. 100.

References

Aden, D. (1990), "Verkehrswesen in Europa, Infrastruktur intelligenter nutzen", in Bonny, C. (Editor), *Jahrbuch der Logistik*, Verlagsgruppe Handelsblatt, Düsseldorf, Frankfurt, pp. 22-46.

Andersen Consulting (1993), "Guide to Distribution Software 1993", Institute of Physical Distribution and Logistics Management (Publisher), Douglas House, Queens Square, Corby, Northants, NN17 1PL.

Anderson, E.; Wujin, C. and Barton, W. (1987), "Industrial Purchasing: An Empirical Exploration of the Buy-Class Framework", Journal of Marketing, Vol. 51, July, pp. 71 - 86.

ANON (1977), "Data Processing in the Grocery Trade", The Institute of Grocery Distribution, Letchmore Heath, Watford, WD28DQ, Tel: 0923 857141.

ANON (1993a), "On Schedule", Logistics Europe, Vol. 1, No. 2, April, p. 53.

ANON (1993b), "The Route to a First-Class Solution", Distribution, Vol. 6, No. 2, June, p. 42.

Arthur D. Little, Inc. (1994), "Productivity Comparison Macintosh vs. Windows", January.

Aubin, J. (1992), "Scheduling Ambulances", Interfaces, Vol. 22, No. 2, March-April, pp. 1-10.

Backhaus, K.; Erichson, B.; Plinke, W. und Weiber, R. (1987), "Multivariate Analysemethoden", 4. Auflage, Berlin, Springer Verlag.

Bagozzi, R. P.; Tybout, A. M.; Craig, C. S. and Sternthal, B. (1979), "The Construct Validity of the Tripartite Classification of Attitudes", Journal of Marketing Research, Vol. 16, February, pp. 88-95.

Bailey, J. E. and Pearson, S. W. (1983), "Development of a Tool for Measuring and Analyzing Computer User Satisfaction", Management Science, Vol. 29, No. 5, pp. 530-544.

Baker, M. J. (1992), "Marketing Strategy and Management", Macmillan Press Ltd., 2nd Edition, London.

Ballou, R. H. (1978), "Basic Business Logistics", Prentice-Hall, Englewoods Cliffs, New Jersey.

Bank of England (1993), "Inflation Report", Bank of England Quarterly Bulletin, Burrups Ltd., St. Eves PLC (Publisher), ISBN 1857300416.

Bargl, M. (1992), "Tourenplanung in der Transportwirschaft - Viel gelobt selten genutzt?", Logistik im Unternehmen, No. 6, pp. 80-84.

Bargl, M. (1994), "Akzeptanz und Effizienz computergestützter Dispositionssystem in der Transportwirtschaft", in Gemünden, H. G. and Gaul, W. (Editors), *Entscheidungsunterstützung für ökonomische Probleme 4*, Peter Lang Verlag, Frankfurt am Main.

Barklay, D. W. (1991), "Interdepartmental Conflict in Organizational Buying: The Impact of the Organisational Context", Journal of Marketing Research, Vol. 28, May, pp. 145-159.

Baroudi, J. J.; Olson, M. H. and Ives, B. (1986), "An Empirical Study of the Impact of User Involvement on System Usage and Information Satisfaction", Communications of the A.C.M., Vol. 29, No. 3, pp. 232-238.

Bass, F, M. (1986), "The Adoption of a Marketing Model: Comments and Observations", in Mahajan, V. and Wind, Y. (Editors), *Innovation Diffusion Models of New Product Acceptance*, Ballinger Publishing Co., Cambridge.

Bass, F, M. (1969), "A New Product Growth Model for Consumer Durables", Management Science, Vol. 15, January, pp. 215-227.

Belardo, S.; Duchessi, P. and Seagle, J. P. (1985), "Microcomputer Graphics in Support of Vehicle Routing", Interfaces, Vol. 15, No. 6, November-December, pp. 84-92.

Bell, W. Y.; Dalberto, L. M.; Fisher, M. L.; Greenfield, A. J.; Jaikumar, R.; Kedia, P.; Mack, R. G.; Prutzman, P. J. (1983), "Improving the Distribution of Industrial Gases with an On-line Computerised Routing and Scheduling Optimizer", Interfaces, Vol. 13, No. 6, pp. 4-23.

Bocxe, M. A. G. and Tilanus, C. B. (1985), "Testing Vehicle Scheduling Programs for Milk Collection", European Journal of Operational Research, Vol. 20, pp. 25-33.

Bodin, L.; Golden, B. (1981), "Classification in Vehicle Routing and Scheduling", Networks, Vol. 11, pp. 197-198.

Bodin, L.; Fagin, G.; Welebny, R. and Greenberg, J. (1989), "The Design of a Computerized Sanitation Vehicle Routing and Scheduling System for the Town of Oyster Bay, New York", Computers in Operations Research, Vol. 16, No. 1, pp. 45-54.

Bodin, L.; Golden, B.; Assad, A. and Ball, M. (1983), "Routing and Scheduling of Vehicles and Crews, The State of the Art", Computers & Operations Research, Vol. 10, No. 2, pp. 63-201.

Böker, F. (1987), "A Stochastic First Purchase Diffusion Model: A Counting Process Approach", Journal of Marketing Research, Vol. 24, February, pp. 64-73.

Bortz, J. (1993), "Statistik für Sozialwissenschaftler", 4. überarbeitete Auflage, Springer Verlag, Berlin Heidelberg.

Bowman, R. (1992), "A Computerized Route to Better Decisions", Distribution, Vol. 91, No. 5, May, pp. 28-34.

Bradley, M. F. (1977), "Buying Behaviour in Ireland's Public Sector", Industrial Marketing Management", Vol. 6, August, pp. 251-258.

Brendel, T. (1987), "Dialoggestützte Tourenplanung unter besonderer Berücksichtigung von Belieferungszeitintervallen", Peter Lang Verlag, Frankfurt am Main, Bern, New York.

Brewers' Society (1993a), "Statistical Handbook 1993, A Compilation of Drinks Industry Statistics", The Brewers' Society, Brewing Publications Ltd., London.

Brewers' Society (1993b), "Beer Facts 1993", The Brewers' Society, London.

Brown, G. G.; Ellis, C. J.; Graves, G. W. and Ronen, D. (1987), "Real-Time, Wide Area Dispatch of Mobil Tank Trucks", Interfaces, Vol. 17, No. 1, January-February, pp. 107-120.

Brown, G. G. and Graves, G. W. (1981), "Real-Time Dispatch of Petroleum Tank Trucks", Management Science, Vol. 27, No. 1, January, pp. 19 - 32.

Bryman, A. (1988), "Quantity and Quality in Social Research", Uniwin Hyman Ltd., London.

Burnes, B. (1992), "Managing Change, A Strategic Approach to Organisational Development and Renewal", Pitman Publishing, London.

Candaluppi, L. and Hug, R. (1986), "Tourenplanung auf dem Personal-Computer", Output, No. 9, pp. 53-58.

Canen, A. G. and Pizzolato, N. D. (1993), "The Vehicle Routing Problem: A Managerial Report", Logistics Focus, The Journal of the Institute of Logistics, Vol. 1, No. 2, September, pp. 6-9.

Cardozo, R. N. (1983), "Modelling Organizational Buying as a Sequence of Decisions", Industrial Marketing Management, Vol. 12, pp. 75-81.

Cardozo, R. N. and Cagley J. W. (1971), "Experimental Study of Industrial Buyer Behavior", Journal of Marketing Research, Vol. 8, August, pp. 329-334.

Cats-Baril, W. L. and Huber, G. P. (1987), "Decision Support Systems for Ill-Structured Problems: An Empirical Study", Decision Science, Vol. 18, No. 3, pp. 350-372.

Chervany, N. I.; Dickinson, G. W. and Kozar, K. A. (1971), "An Experimental Gaming Framework for Investigating the Influence of Management Information Systems on Decision Effectiveness", Management Information Systems Research Center, Working Paper, University of Minnesota, pp. 71-12.

Christofides, N. (1981), "Uses of Vehicle Routing and Scheduling Systems in Strategic Distribution Planning", Scandinavian Journal of Materials Administration (SJMA), Vol. 7, No. 2, pp. 39-55.

Christopher, M. (1986), "Implementing Logistics Strategy", International Journal of Physical Distribution & Materials Management (IJPD & MM), Vol. 16, No. 1, pp. 52-62.

Churchill, G. A. (1979), "A Paradigm for Developing Better Measures of Marketing Constructs", Journal of Marketing Research, Vol. 16, February, pp. 64-73.

Clopton, S. W. (1984), "Seller and Buying Firm Factors Affecting Industrial Buyers' Negotiation Behavior and Outcome", Journal of Marketing Research, Vol. 21, February, pp. 39-53.

Comrey, A. L. (1973), "A First Course in Factor Analysis", Academic Press, New York

Cooper, J. C. and Jessop, A. T. (1983), "Planning Multi-Drop Deliveries", Discussion Paper No. 12, Transport Studies Group, Polytechnic of Central London, April.

Cooper, R. B. (1988), "Review of Management Information Systems: A Management Support Emphasis", Information Processing & Management, Vol. 24, No. 1, pp. 73-101.

Davis, D. L.; Davis, R. D. and Shrode, W. S. (1987), "Decision Support Systems (DSS) Design for Operations Managers: An Empirical Study of the Impact of Report Design and Decision Style on Effective Choice", Journal of Operations Management - Combined Issue, Vol. 7, Nos. 1 and 2, October, pp. 47-62.

Davis, T. (1993), "Street Smart", Beverage World, Vol. 112, No.1556, December, p. 62.

Department of Transport (1993), "Transport Statistics Great Britain 1993", Her Majesty's Stationery Office (HMSO), London.

DeSanctis, G. and Gallupe, R. B. (1987), " A Foundation for the Study of Group Decision Support Systems", Management Science, Vol. 33, No. 5, May, pp. 589-609.

Doll, W. J. and Torkzadeh, G. (1989), "A Discrepancy Model of End-User Computing Involvement", Management Science, Vol. 35, No. 10, pp. 1151-1171.

Domschke, W. (1985), "Logistik: Transport, Grundlagen, lineare Transport- und Umladeprobleme", R. Oldenbourg Verlag, München.

Domschke, W. (1990), "Logistik: Rundreisen und Touren", 3. Auflage, R. Oldenbourg Verlag, München.

Dos Santos, B. L. (1989), "Information Systems: Similarities and Differences Across Organizations", OMEGA International Journal of Management Science, Vol. 17, No. 1, pp. 9-20.

Dos Santos, B. L. and Bariff, M. L. (1988), "A Study of User Interface Aids for Model-Oriented Decision Support Systems", Management Science, Vol. 34, No. 4, April, pp. 461-468.

Dwyer, F. R.; Schnurr, P. H. and Oh, S. (1987), "Developing Buyer-Seller Relationships", Journal of Marketing, Vol. 51, April, pp. 11-27.

Eastburn, M. P. and Christensen, L. R. (1986), "Reducing Vehicle Fleet Costs: A Case Study", International Journal of Physical Distribution & Materials Management (IJPD&MM), Vol. 16, No. 1, pp. 63-72.

Eckstein, W.; Heusch, H. and Schmidt, K. (1988), "Informationssystem - Basis für Kooperation im Straßengüterverkehr, Das Modell INTAKT", Internationales Symposium Forschung und neue Technologien im Verkehr, 6-8 June, Hamburg.

Edström, A. (1977), "User Influence and the Success of MIS Projects: A Contingency Approach", Human Relations, Vol. 30, No. 7, pp. 589-607.

Eibl, P. G.; Mackenzie, R. and Kidner, D. (1994), "Vehicle Routing and Scheduling Software in the Brewing Industry - A Case Study", International Journal of Physical Distribution and Logistics Management (IJPD & LM), Vol. 24, No. 6, 1994, pp. 27 - 37.

Eibl, P. G. (1993a), "Der Einsatz digitaler Straßennetzwerke zur Planung, Steuerung und Kontrolle internationaler Gütertransporte", Angewandte Geographische Informationstechnologie V, Beiträge zum GIS-Symposium, Heft 20, Institut für Geographie der Universität Salzburg, Austria, 7-9 July, pp. 185-198.

Eibl, P. G. (1993b), "The Value of Digitised Road Networks in Planning and Managing Efficient International Distribution", Conference Proceedings of the International Symposium on Logistics, The University of Nottingham, 6-7 July, pp. 237-242.

Eibl, P. G. (1993c), "Road Transport Information Systems for European Distribution", International Journal of Physical Distribution and Logistics Management (IJPD & LM), Vol. 23, No. 9, pp. 21-27.

Eibl, P. G. (1994), "Design and Use of Digitised Road Networks in International Road Transport", Logistics Information Management, Vol. 7, No. 4, pp. 40 - 48.

Eibl, P. G. (1994), "STIS-Einsatz im Güterverkehr", in Hossner, R. (Editor), *Jahrbuch der Logistik*, Verlagsgruppe Handelsblatt GmbH, Düsseldorf, pp. 96-101.

Eibl, P. G. and Kidner, D. (1994a), "The Road Ahead", Logistics Europe, Vol. 2, No. 3, May, pp. 54-56.

Eibl, P. G. and Kidner, D. (1994b), "Making a Strategic Selection", Logistics Europe, Vol. 2, No. 4, June, pp. 38-40.

Eibl, P. G. and Mackenzie, R. (1993), "An Application of Computerised Vehicle Routing and Scheduling: Benefits, Problems and Organisational Consequences", Proceedings of the 26th International Symposium on Automotive Technology and Automation (ISATA): Dedicated Conference on Advanced Transport Telematics (ATT)/Intelligent Vehicle-Highway Systems (IVHS) - Towards Development and Implementation, Aachen, Germany, 13-17 September, pp. 39-46.

Eibl, P. G. and Mackenzie, R. (1994a), "Computerised Vehicle Routing and Scheduling at Scottish & Newcastle", Brewer's Guardian, Hampton Publishing Ltd., Hampton, UK, Vol. 123, No 5, May, pp. 28-31.

Eibl, P. G. and Mackenzie, R. (1994b), "Using Interactive Vehicle Routing and Scheduling Software", Logistics Focus, Journal of the Institute of Logistics (IL), Northampton, Vol. 2, No. 3, p. 10-13.

Ein-Dor, P.; Segev, E. and Steinfeld, A. (1981), "Use of Management Information Systems: An Empirical Study", Proceedings of the 2nd International Conference on Information Systems, Mass, 7 December, pp. 215-228.

Ein-Dor, P. and Segev, E. (1981), "A Paradigm for Management Information Systems", Praeger Publishers, New York.

Ellinger, T.; Asmussen, R. and Schirmer, A. (1982), "Transportoptimierung durch flexible Lieferplanung", Schriftenreihe: Kostensenkung durch erfolgreichen Einsatz von Operations Research, Rationalisierungs-Kuratorium der Deutschen Wirtschaft (RKW), e. V.

Ellinger, T. (1980), "Fuhrparkrationalisierung durch Tourenplanung", Schriftenreihe: Kostensenkung durch erfolgreichen Einsatz von Operations Research, Rationalisierungs-Kuratorium der Deutschen Wirtschaft (RKW) e. V.

Engel, F. J.; Blackwell, R. D. and Miniard, P. W. (1986), "Consumer Behavior", 5th Edition, The Dryden Press, New York.

Erkut, E. and MacLean, D. (1992), "Alberta's Energy Efficiency Branch Conducts Transport Audits", Interfaces, Vol. 22, No. 3, May-June, pp. 15-21.

Eurostat (1993), "Transport: Annual Statistics 1970-1990", January.

Evans, J. (Editor), (1992), "Good Beer Guide 1992", Campaign for Real Ale Ltd., St. Albans, Herts, Cambridge University Press.

Evans, S. R. and Norback, J. P. (1985), "The Impact of a Decision-Support System for Vehicle Routeing in a Foodservice Supply Situation", Journal of the Operational Research Society, Vol. 36, No. 6, pp. 467-472.

Fehr, G. and Fontaine, J. (1987), "Mit EDV auf Touren, Rechnergestützte Tourenplanung im Handel", Rationalisierungs-Gesellschaft des Handels (RGH) m.b.H, Köln.

Fink, A. and Kosecoff, J. (1985), "How to Conduct Surveys", Sage Publications, London.

Fisher, M. L.; Greenfield, A. J.; Jaikumar, R. and Lester III, J. T. (1982), "A Computerised Vehicle Routing Application", Interfaces, Vol. 12, No. 4, August, pp. 42-52.

Foulds, L. R.; Tham, J. P. and O'Brien, L. E. (1977), "Computer-Based Milk Tanker Scheduling", New Zealand Journal of Daily Science and Technology, Vol. 12., pp. 141-145.

Fürst, W. L. (1979), "An Investigation into the Factors that May Affect the Perceived Utilization of Computer-Based DSS", Ph.D. Thesis, Texas Technical University.

Fürst, W. L. and Cheney, P. H. (1982), "Factors Affecting the Perceived Utilization of Computer-Based Decision Systems in the Oil Industry", Decision Science, Vol. 13, No. 4, pp. 554-569.

Gatignon, H. and Robertson, T. S. (1985), "A Propositional Inventory for New Diffusion Research", Journal of Consumer Research, Vol. 11, March, pp. 849 - 867.

Geisler, E. and Hoang, W. (1992), "Purchasing Information Technologies: Behavior Patterns in Service Companies", International Journal of Purchasing and Materials Management, Vol. 28, Summer, pp. 38-42.

Gibson, C. F. (1975), "A Methodology for Implementation Research", in Schultz, R. L. and Slevin, D. P. (Editors), *Implementing Operations Research/Management Science*, American Elsevier, New York, p. 53-76.

Ginzberg, M. J. (1979), "A Study of the Information Process", TIMS Studies in the Management Science, Vol. 13, pp. 85-102.

Ginzberg, M. J. (1981a), "Key Recurrent Issues in the MIS Implementation Process", Management Information System Quarterly, Vol. 5, June, pp. 47-59.

Ginzberg, M. J. (1981b), "Early Diagnosis of MIS Implementation Failure: Promising Results and Unanswered Questions", Management Science, Vol. 27, No. 4, pp. 459-478.

Golden, B. L. and Assad, A. A. (Editors), (1988), "Vehicle Routing: Methods and Studies", Studies in Management Science and Systems, Vol. 16, Elsevier Science Publishers B. V., North-Holland, New York.

Golden, B. L. and Wasil, E. A. (1987), "Computerized Vehicle Routing in the Soft Drink Industry", Operations Research, Vol. 35, No. 1, January - February, pp. 6-17.

Goslar, M. D.; Green, G. I. and Hughes, T. H. (1986), "Decision Support Systems: An Empirical Assessment for Decision Making", Decision Science, Vol. 17, No. 1, pp. 79-91.

Gross, R. (1989), "Psychology, The Science of Mind and Behaviour", Hodder & Stoughton, London.

Guise, R. G. (1987), "How to Computerise Your Scheduling ... and Stay Sane", Conference Proceedings, Computers in Transport & International Distribution, Wembley, April.

Hampton Publishing (1992), "Brewery Manual and Who's Who in British Brewing and Scotch Whisky Distilling 1992", Hampton Publishing Ltd., London.

Hellmann, A. (1984), "Theorie und Praxis von Routing-Problemen: Lösungsverfahren zur Tourenplanung im Eindepot- und Mehrdepot-Fall", Dissertation (Ph.D. thesis) im Fachbereich Wirtschaftswissenschaften der Technischen Universität Berlin.

Herlihy, P.; Butler, M. and Pitts, E. (1984), "Estimation of Energy and Cost Savings Arising from Rationalization of Milk Assembly Operations", Commission of the European Communities, Report EUR 9272 EN I.

Hiltz, S. R. and Johnson, K. (1990), "User Satisfaction with Computer-Mediated Communication Systems", Management Science, Vol. 36, No. 6, June, pp. 739-764.

HMSO (1988), "Transport Statistics Great Britain 1977-1987", Her Majesty's Stationery Office (HMSO), Department of Transport, Scottish Development Department, Welsh Office.

Hoja, U. and Graf H.-W. (1988), "Untersuchung der Einsatzmöglichkeit von Mikrocomputern für die rechnergestützte Tourenplanung in kleinen und mittleren Unternehmen - Ergebnisbericht", Fraunhofer-Institut für Transporttechnik und Warendistribution, Dortmund.

Holmes, D. (1989), "The Practical Use of Vehicle Scheduling Software", Conference Proceedings Warehousing and Distribution Management: Strategic and Operational Support Using Software Systems, Heathrow Ambassador Hotel, 4-5 December, pp.69-84.

Holt, J. N. and Watts, A. M. (1988), "Vehicle Routing and Scheduling in the Newspaper Industry", in Golden, B. and Assad, A. (Editors), *Vehicle Routing: Methods and Studies, Studies in Management Science and Systems*, Vol. 16, Elsevier Science Publishers B. V., North-Holland, New York, pp. 347-358.

Hooban, M. and Jones, A., B. (1993), "Coping with the Fear Factor", Logistics Focus, Vol. 1, No. 3, October, pp. 2-3.

Huppertz, J. W., Arenson, S. J. and Evans, R. H. (1978), "An Application of Equity Theory to Buyer-Seller Exchange Situations", Journal of Marketing Research, Vol. 15, May, pp. 250-260.

Hysman, J. H. B. M. (1979), "The Effectiveness of the Cognitive Style Constraint in Implementing Operations Research Proposals", Management Science, Vol. 17, pp. 92-104.

Ihde, G. B. (1972), "Logistik, Physische Aspekte der Güterdistribution", Carl Ernst Poeschel Verlag, Stuttgart.

ILDM (1992), "ILDM Survey of Distribution Costs, A Study into Current Distribution Cost Trends in U. K. Industry 1991/92", Institute of Logistics and Distribution Management, Douglas House, Queens Square, Corby, Northants, NN17 1PL.

Ives, B.; Hamilton, S. and Davis, G. B. (1980), "A Framework for Research in Computer-Based Management Information Systems", Management Science, Vol. 26, No. 9, pp. 910-934.

Ives, B.; Olson, M. H. and Baroudi, J. J. (1983),"The Measurement of User Information Satisfaction", Communication of the ACM, Vol. 26, No. 10, pp. 785-793.

Ives, B. and Olson, M. H. (1984), "User Involvement and MIS Success: A Review of Research", Management Science, Vol. 30, No. 5, May, pp. 586-603.

Jansen, R. (1986), "Logistik, Stand und Entwicklungen für den Getränkefachgroßhandel, Teil 1", Getränkefachgroßhandel, January/February, Nos. 1,2.

Johnston, W. J. and Bonoma, T. (1981), "The Buying Center: Structure and Interaction Patterns", Journal of Marketing, Vol. 45, Summer, pp. 143-156.

Jolliffe, F. R. (1986), "Survey Design and Analysis", Ellis Horwood Ltd, Chichester.

Jordans & Son Ltd. (1989), "Britain's Brewing Industry", Jordans & Son Limited (Publisher).

Joseph, J. (1990), "Arbeitswissenschaftliche Aspekte der betrieblichen Einführung neuer Technologien am Beispiel von Computer Aided Design (CAD)", in Gaul, W. and Gemünden, H. G. (Editors), *Entscheidungsunterstützung für ökonomische Probleme*, Peter Lang Verlag, Frankfurt am Main.

Joubert, W. H. (1972), "Profit Potentials of Physical Distribution", American Management Association, Inc.

Kaztmier, L. J. and Pohl, N. F. (1984), "Basic Statistics for Business and Economics", McGraw-Hill, Singapore.

Kelly, P. (1974), "Functions Performed in Industrial Purchase Decisions with Implications for Marketing Strategy", Journal of Business Research, Vol. 2, October, pp. 321-433

Kendall, K. E.; Duffington, T. R. and Kendall, J. E. (1987), "The Relationship of Organizational Subcultures to DSS and Satisfaction", Human Systems, Vol. 7, No. 1, pp. 31-39.

Kerlinger, F. N. (1970), "Foundations of Behavioral Research, Educational and Psychological Enquiry", Holt, Rinehart & Winston, London.

Klaus, P. (1990), "Computereinsatz im Fuhrpark lohnt sich in jedem Fall", Deutsche Verkehrszeitung (DVZ), No. 135, 10.11.1990, P. 39.

Klauss, R. and Jewett, J. (1974), "Issues and Methodology for MIS Research", Paper Presented at Joint TIMS/ORSA Meeting, April.

Kohli, A. (1989), "Determinants of Influence in Organisational Buying: A Contingency Approach", Journal of Marketing, Vol. 53, July, pp. 50-65.

Kolb, A. and Frohman, A. L. (1971), "An Organisational Development Approach to Consulting", Sloan Management Review, Vol.12, pp. 51-65.

Kotler, P. (1994), "Marketing Management - Analysis, Planning, Implementation and Control", 8th Edition, Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Kotler, P. and Armstrong, G. (1991), "Principles of Marketing", 5th Edition, Prentice-Hall International, Englewood Cliffs, New Jersey.

KPMG (1991), "The Management of Information Technology in the Distribution Industry", KPMG Management Consulting, Institute of Logistics & Distribution Management (Publisher), Douglas House, Queens Square, Corby, Northants, NN17 1PL.

Kreuzpainter, P. (1972), " Die Anwendung von Operations Research Modellen im Transportwesen der Brauerei" Fakultät für Bauwesen und Lebensmitteltechnologie der Technischen Universität München.

Kubicek, H. (1975a), "Empirische Sozialforschung, Konzeption und Methodik", Poeschel Verlag, Stuttgart.

Kubicek, H. (1975b), "Informationstechnologie und organisatorische Regelungen", Konzeptionelle Grundlagen einer empirischen Theorie der organisatorischen Gestaltung des Benutzerbereichs in computergestützten Informationssystemen", Duncker & Humblot, Berlin.

Langley, C. J.; Carlisle, D. P.; Probst, St. B; Biggs, D. F. and Cail, R. E. (1988), "Microcomputers as a Logistics Information Strategy", International Journal of Physical Distribution and Materials Management (IJPD & MM), Vol. 18, No. 6, pp. 11-17.

Lazarsfeld, P. F. (1958), "Evidence and Inference in Social Research", Daedalus, Vol. 87, No. 4, pp. 99-130.

Lewin, K. (1952), "Group Decision and Social Change", in Newcomb and Hartley (Editors), *Readings in Social Psychology*, Henry Holt, New York, pp. 459-473.

Lilien, G. L. and Wong, A. (1984), "An Exploratory Investigation of the Structure of the Buying Center in the Metalworking Industry", Journal of Marketing Research, Vol. 21, February, pp. 1-11.

Loudon, D. L. and Della Bitta, A. J (1993), "Consumer Behavior, Concepts and Applications", 4th Edition, McGraw-Hill, Inc., New York.

Lucas, H. C., Jr.; Ginzberg, M. J. and Schultz, R. L. (1990), "Information Systems Implementation: Testing a Structural Model", Ablex Publishing Corporation, Norwood, New Jersey.

Lucas, H. C., Jr. (1973), "A Descriptive Model of Information Systems in the Context of the Organisation", Database, Vol. 5, No. 2, pp. 27-39.

Lucas, H. C., Jr. (1974), "Measuring Employee Reactions to Computer Operations", Sloan Management Review, Vol. 15, No. 3 , pp. 59-67.

Lucas, H. C., Jr. (1975), "Why Information Systems Fail", Columbia University Press, New York and London.

Lucas, H. C., Jr. (1976), "The Analysis, Design and Implementation of Information Systems", McGraw-Hill Book Company, New York, St. Louis.

Lucas, H. C., Jr. (1976), "The Implementation of Computer-Based Models", National Association of Accountants, 919 Third Avenue, New York 10022.

Lucas, H. C., Jr. (1978), "Empirical Evidence for a Descriptive Model of Implementation", Management Information Systems (MIS) Quarterly, Vol. 2, No. 1, pp. 27-41.

Mahajan, V.; Muller, E. and Srivastava, R. K. (1990a), "Determination of Adopter Categories by Using Innovation Diffusion Models", Journal of Marketing Research, Vol. 27, February, pp. 37-50.

Mahajan, V.; Muller, E. and Bass, F. M. (1990b), "New Product Diffusion Models in Marketing: A Review and Directions for Research", Journal of Marketing, Vol. 64, January, pp. 1-26.

Mahajan, V. and Muller, E. (1979), "Innovation Diffusion and New Product Growth Models in Marketing", Journal of Marketing, Vol. 43, Fall, pp. 55-68.

Mahatoo, W. H. (1985), "The Dynamics of Consumer Behaviour", John Wiley & Son Canada Ltd, Toronto.

Maier, M. (1980), "Schwachstellen, Problemlösungen und Perspektiven der Vertriebslogistik in der Getränkeindustrie", in Lück, W. (Editor), *Logistik*, Band 2 der Schriftenreihe der Betriebswirtschaftlichen Abteilung der Versuchs- und Lehranstalt für Brauerei (VLB) in Berlin.

Maisch, A. M. (1979), " A User's Behaviour Towards his MIS", Management Information Systems (MIS) Quarterly", Vol. 3, No. 1, pp. 39-52.

Manugistics (1992), "Statgraphics Plus, Version 6.0, Reference Manual", Manugistics, Incorporation (publisher/supplier), USA.

Mason, R. O. and Mitroff, I. I. (1973), "A Program for Research on Management Information Systems", Management Science, Vol. 19, No. 5, pp. 475-485.

Matthäus, F. (1978), "Tourenplanung - Verfahren zur Einsatzdisposition von Fuhrparks", S. Toeche-Mittler Verlag, Darmstadt.

McDaniel, C. and Gates, R. (1991), "Contemporary Marketing Research", West Publication Company, St. Paul, New York, Los Angeles, San Francisco.

McKeen, J. D. (1983), "Successful Development Strategies for Business Application Systems", Management Information Systems (MIS) Quarterly, Vol. 7, No. 3, pp. 47-59.

Meador, C. L.; Guyote, M. J. and Keen, P. G. W. (1984), "Setting Priorities for DSS Development", Management Information Systems (MIS) Quarterly, Vol. 8, No. 2, pp. 117-129.

Meall, L. (1993), "The Navigator on Your Dashboard", Accountancy (ACE), Vol. 112, No. 1200, August, pp. 54-55

Messick, S. (1988), "Validity", in Linn, R. L. (Editor), *Educational Measurement*, 3rd Edition, American Council on Education, Macmillan Publishers, New York.

Michaels, R. E.; Day, R. L. and Joachimsthaler, E. A. (1987), "Role Stress Among Industrial Buyers: An Integrative Model", Journal of Marketing, Vol. 51, April, pp. 28-45.

Midgley, D. F. (1977), "Innovation and New Product Marketing", Croom Helm, London.

Miller, C. M.; McIntyre, S. H. and Mantrala, M. K. (1993), "Toward Formalizing Fashion Theory", Journal of Marketing, Vol. 30, May, pp. 142-157.

More, R. A. (1992), "Managing New Technology Adoption", Business Quarterly (Canada), Vol. 56, No. 4, pp. 69-73.

Moriatry, R. T., Jr. and Spekman, R. E. (1984), "An Empirical Investigation of the Information Sources Used During the Industrial Buying Process", Journal of Marketing Research, Vol. 21, May, pp. 137-47.

Motor Transport (1992), "Cost Tables", Motor Transport, April.

Mowat, J. (1978), "The Cadbury Schweppes Approach to Load Planning", Proceedings of Operational Research Society Conference, A Summary of O. R. Work Into the Scheduling of Vehicles for Local Delivery Operations, York, 5. October.

Murray, W. (1992), "A Computerised Scheduling System for Cars Used as Delivery Vans, A Case Study", Logistics Focus, The Journal of the Institute of Logistics and Distribution Management (ILDM), Vol. 11, No. 5, June, pp. 27-31.

Mykytyn, P. P., Jr. (1988), " End User Perception of DSS Training", Journal of Systems Management, Vol. 39, No. 6, pp. 32-35.

Nagel, F. (1978), "NUDDY - Ein Verfahren zur Lösung großer Mehrdepot-Lieferprobleme", Dissertation (Ph.D. thesis) am Institut für Landwirtschaftliche Betriebs- und Arbeitslehre der Christian-Albrechts-Universität Kiel.

Newbold, P. (1991), "Statistics for Business and Economics", 3rd Edition, Prentice-Hall International Inc., Division of Simon & Schuster, Englewood Cliffs, New Jersey.

Organ, D. W. and Bateman, T. (1986), "Organisational Behavior, An Applied Psychological Approach", 3rd Edition, BPI IRWIN, Homewood, Illinois.

Osgood, C. E. (1962), "Studies on the Generality of Affective Meaning Systems", American Psychology, Vol. 17, No. 1, January, pp. 10-28.

Ozanne, U. B. and Churchill, G. A., Jr. (1971), "Five Dimensions of the Industrial Adoption Process", Journal of Marketing Research, Vol. 8, August, pp. 322-328.

Paessens, H. (1981), "Tourenplanung bei der regionalen Hausmüllentsorgung", Dissertation (Ph.D. thesis) an der Fakultät für Bauingenieur- und Vermessungswesen der Universität (TH) Karlsruhe.

Pape, H. (1988), "Tourenplanung im Güterverkehr, Anforderungen und Modell für eine Problemstellung mit Von-Nach-Beziehungen", Zeitschrift für Logistik, Februar, pp. 51-54.

Parkin, J. (1992), "Vehicle Routing and Scheduling", UNICOM Seminars, Proceedings of Logistics of the Supply Chain; Planning, Management and IT Support Logistics for Europe in the 1990's, Sterling Hotel, Heathrow, London, 28-29 April, pp. 155-160.

Parkin, J. and Probert, S. (1987), "Information Technology in Road Haulage and Distribution", Focus on Distribution and Logistics Management, Vol. 6, No. 8, pp. 14-26.

Peters, M. J. (1990), "Information Technology and Distribution", in Cooper, J. (Editor), *Logistics and Distribution Planning, Strategies for Management*, Revised Edition, Kogan Page, London, pp. 209-222.

Peters, M. J. and Doganis, R. (1987), "Information Technology in Delivery Control", - Transport Studies Group, Research Report No. 12, Polytechnic of Central London, February.

Peterson, R. A. (1973), "A Note on Optimal Adopter Category Determination", Journal of Marketing Research, Vol. 10, August, pp. 325-329

Pfohl, H.-Ch. (1990), "Logistiksysteme, Betriebswirtschaftliche Grundlagen", 3. Auflage, Springer Verlag, Berlin.

Polak, J. (1988), "Expert Systems for Vehicle Routing and Scheduling: Motivation, Prospects and Problems", Conference paper of the 30th Annual Conference of the Operational Research Society.

Polak, J. (1990), "Computer-Based Vehicle Routeing and Scheduling: Past, Present and Future", in Cooper, J. (Editor), *Logistics and Distribution Planning, Strategies for Management*, Revised Edition, Kogan Page, London, pp. 80-105.

Probol, M. G. (1979), "Tourenplanung mit EDV unter besonderer Berücksichtigung eines Unternehmens des Eisen- und Bausstoffgroßhandels", Dissertation (Ph.D. Thesis) an der Fakultät für Maschinenbau und Elektrotechnik der Technischen Universität Carolo-Wilhemina zu Braunschweig.

Ramprasad, A. (1987), "Cognitive Processes as a Basis for MIS and DSS Design", Management Science, Vol. 33, No. 2, February, pp. 139-148.

Rao, V. S. and Jarvenpaa, S. L. (1991), "Computer Support of Groups: Theory-based Models for GDSS Research", Management Science, Vol. 37, No. 10, October, pp. 1347-1362.

Reward Group (1993), "Salary Survey", Reward House, Diamond Way, Stone Business Park, Stone, Staffordshire ST15 OSD, June.

Riebel, O. (1977), "Betriebswirtschaftliche Kriterien für die Entscheidungen zwischen Eigen- und Fremdtransport", Heft 4 der Schriftenreihe der Gesellschaft für Verkehrsbetriebslehre (GFVB) e.V., Frankfurt/Main.

Robertson, T. S. (1971), "Innovative Behaviour and Communication", Holt, Rinehart and Winston, New York.

Robertson, T. S. (1974), A Critical Examination of "Adoption Process" Models of Consumer Behavior", in Sheth, J. N. (Editor), *Models of Buyer Behavior - Conceptual, Quantitative, and Empirical*, Harper & Row, Publishers, New York.

Robertson, T. S. and Gatignon, H. (1986), "Competitive Effects on Technology Diffusion", Journal of Marketing, Vol. 50, July, pp. 1-12.

Robinson, P. J. and Faris, C. W. (1967), "Industrial Buying and Creative Marketing", Boston, Allyn & Bacon.

Rogers, E. M. (1962), "Diffusion of Innovations", The Free Press, New York.

Rogge, H.-J. (1981), "Marktforschung", Studienbücher der Wirtschaft, Carl Hanser Verlag, München, Wien.

Rommerskirchen, S. (1992). "Zukünftige Transportmärkte, Verkehr im neuen Europa", in Bonny, C. (Editor), *Jahrbuch der Logistik*, Verlagsgruppe Handelsblatt, Düsseldorf, Frankfurt, pp. 22-25.

Ronchetto, J. R.; Hutt, M. D., Jr. and Reingen, P. H. (1989), "Embedded Influence Patterns in Organizational Buying Systems", Journal of Marketing, Vol. 53, October, pp. 51-62.

Roscoe, J. T. (1975), "Fundamental Research Statistics for the Behavioral Sciences", Second Edition, Holt, Rinehart and Winston, Inc., New York.

Rothhaar, R. (1980), "Erfahrungen mit dem Siemens-Programmsystem TRAFIC", in Lück, W. (Editor), in Lück, W. (Editor), *Logistik*, Band 2 der Schriftenreihe der Betriebswirtschaftlichen Abteilung der Versuchs- und Lehranstalt für Brauerei (VLB) in Berlin.

Rupper, P. (1987), "Logistik - Eine neue Unternehmensdimension", in Rupper, P. (Editor), *Unternehmenslogistik, Ein Handbuch für die Einführung und Ausbau der Logistik im Unternehmen*, Verlag Industrielle Organisation, Zürich.

Rushton, A. and Oxley, J. (1989), "Handbook of Logistics and Distribution Management", Kogan Page.

Sanders, G. L. (1984), "MIS/DSS Success Measure Systems", Systems, Objectives and Solutions, Vol. 4, pp. 29-34.

Sanders, G. L. and Courtney, J. F. (1985), "A Field Study of Organisational Factors Influencing DSS Success", Management Information Systems (MIS) Quarterly, Vol. 9, No. 1, March, pp. 77-93.

Schein, E. H. (1961), "Management Development as a Process of Influence", Industrial Management Review, Vol. 2, pp. 59 - 77.

Schein, E. H. (1972), "Professional Education - Some New Directions", McGraw-Hill, New York, St. Louis, San Francisco, pp. 75-95.

Schneider, O. E. (1978), "Die langfristige Optimierung der physischen Distribution in der Brauerei", Band 5 der Schriftenreihe des Betriebswirtschaftliche Instituts der Universität Basel.

Schnell, R.; Hill, P. B. and Esser, E. (1993), "Methoden der empirischen Sozialforschung", 4. überarbeitete Auflage, München, R. Oldenbourg Verlag.

Schroeder, H. M.; Driver, M. J. and Streufert, S. (1967), "Human Information Processing", Holt, Rinehard and Winston, New York, Chicago, San Francisco, Toronto, London.

Schulz, R. L. and Slevin, D. P. (1975), "Implementing Operations Research/Management Science", American Elsevier Publishing Company, New York, London, Amsterdam.

SCRP (1972), "Sample Design & Selection", Technical Manual No. 2, Survey & Community Planning Research, London.

Sculli, D.; Mok, K. C. and Cheung, S. H. (1987), "Scheduling Vehicles for Refuse Collection", Journal of the Operational Research Society, Vol. 38, No. 3, pp. 233-239.

Sharda, R.; Barr, S. H. and McDonnell, J. C. (1988), "Decision Support System Effectiveness: A Review and an Empirical Test", Management Science, Vol. 34, No. 2, pp. 139-159.

Sharma, A. (1994), "Organizational Culture and Adoption of High-technology Products", Journal of Marketing Management, Vol. 10, pp. 513-526.

Sharman, G. (1992), "The Rediscovery of Logistics", in Christopher, M. (Editor), *Logistics, The Strategic Issues*, Chapman & Hall, London.

Sheth, J. N. (1973), "A Model of Industrial Buyer Behavior", Journal of Marketing, Vol. 37, October, pp. 50-56.

Sheth, J. N. (1974), "Models of Buyer Behavior - Conceptual, Quantitative, and Empirical", Harper & Row, New York.

Shimp, T. A. and Sharma, S. S. (1987), "Consumer Ethnocentrism, Construction and Validation of the CETSCALE", Journal of Marketing Research, Vol. 24, August, pp. 280-290.

Sieber, S. D. (1973), "The Integration of Fieldwork and Survey Methods", American Sociological Review, Vol. 78, No. 6, pp. 1335-1359.

Siegert, H.-Ch. (1988), "EDV Unterstützung im Fuhrpark, Fuhrparkinformations- und Tourenplanungssysteme", Verlag moderne industrie AG & Co, Landsberg/Lech.

Sorensen, B. (1986), "Interactive Distribution Planning", Ph.D. Thesis at the Institute of Mathematical Statistics and Operations Research (IMSOR), Technical University of Denmark (DTH).

Spekman, R. E and Stern, L. W. (1979), "Environmental Uncertainty and Buying Group Structure: An Empirical Investigation", Journal of Marketing, Vol. 43, Spring, pp. 54-64.

Spekman, R. E. and Grønhaug, K. (1986), "Buying Centres: Conceptual and Methodological Issues", European Journal of Marketing, Vol. 20, No. 7, pp. 50-63.

Stacey, P. J. (1983), "Practical Vehicle Routing Using Computer Programs", Journal of the Operational Research Society, Vol. 34, No. 10, pp. 975-981.

Steers, R. M. (1975), "Problems in the Measurement of Organisational Effectiveness", Administrative Science Quarterly, Vol. 20, December, pp. 546- 558.

Stinchcombe, A. L. (1964), "Rebellion in a High School", Quadrangle, Chicago.

Straub, D. W. and Carlson, C. L. (1989), "Validating Instruments in MIS Research", Management Information Systems (MIS) Quarterly, Vol. 13. No. 2, June, pp. 147-169.

Sussams, J. (1984), "The Future for Computerised Vehicle-Load Planning Systems", Journal of the Operational Research Society, Vol. 35, No. 11, pp. 963-966.

Tabachnick, B. G. and Fidell, L. S. (1989), "Using Multivariate Statistics", 2nd Edition, Harper & Row, New York.

Thorpe, J. C. (1992), "Vehicle Scheduling", Ph.D. Thesis, Faculty of Technology, University of Manchester.

Tull, D. S. and Albaum, G. S (1973), "Survey Research - A Decisional Approach", International Textbook Company Ltd., Aylesbury, Bucks.

Urbain, G. L. and Star, S, H. (1991), "Advance Marketing Strategy: Phenomena, Analysis and Decisions", Prentice-Hall International Inc., Englewood Cliffs, New Jersey.

Van Vliet, A.; Boender, C. G. E.; Rinnooy Kan, A. H. G. (1992), "Interactive Optimization of Bulk Sugar Deliveries", Interfaces, Vol. 22, No. 3, May/June, pp. 4-14.

Vaterrodt, H.-J. (1974), "Zum Problem der Tourenplanung - Modelle und Lösungsverfahren bei Sicherheit und Unsicherheit für Ein- und Mehrperiodenplanung", Dissertation (Ph.D. Thesis) and der Fakultät für Betriebswirtschaftslehre der Universität Mannheim.

Waters, C. D. J. (1984), "Interactive Vehicle Routing", Journal of the Operational Research Society, Vol. 35, No. 9, pp. 821-826.

Waters, C. D. J. (1986), "Solution Procedures for Vehicle Scheduling Problems", Ph.D. Thesis, University of Strathclyde, Department of Operational Research, Glasgow.

Waters, C. D. J. (1990), "Computer Use in the Trucking Industry", International Journal of Physical Distribution and Logistics Management (ILPD & LM), Vol. 20, No. 9, pp. 24 - 31.

Webb, M. (1972), Transporting Goods by Road", London School of Economics and Political Science, London.

Webster, F. E., Jr. (1991), "Industrial Marketing Strategy", 3rd Edition, John Wiley & Sons, Inc., New York, Toronto

Webster, F. E., Jr. and Wind, Y. (1972a), "A General Model for Understanding Organizational Buying Behavior", Journal of Marketing, Vol. 36, April, pp. 12-19.

Webster, F. E., Jr. and Wind, Y. (1972b), "Organizational Buying Behaviour", Prentice-Hall, Englewood Cliffs, New Jersey.

Weidner, W. (1980), "Kooperation zwischen Wirtschaft und Spedition, Schwerpunkt: Nahrungsverteilung", Brauwelt, No. 39, pp. 1431- 1433.

Welsch, G. M. (1981), "Successful Implementation of Decision Support Systems: The Role of the Information Transfer Specialist", Proceedings of the 13th annual meeting of AIDS, Boston, Massachusetts, pp. 206-208.

Wilson, R. M. S. and Galligan C. (1992), "Strategic Marketing Management - Planning, Implementation and Control, 1st Edition, Butterworth and Heinemann, Oxford.

Willemsen, E. W. (1974), "Understanding Statistical Reasoning - How to Evaluate Research Literature in the Behavioral Sciences", Atkinson, R. C., Freedman, J. and Thompson, R. F. (Editors), W. H. Freeman and Company, San Francisco.

Wind, Y. (1978), "Organizational Buying Behaviour", in Zaltman, G. and Bonoma, T. (Editors), *Review of Marketing*, American Marketing Association, Chicago, pp. 160-193.

Wind, Y. and Thomas, J. (1980), "Conceptual and Methodological Issues in Organisational Buying Behaviour", European Journal of Marketing, Vol. 14, No. 5/6, pp. 239-263.

Witkin, H. A.; Oltman, P. K.; Raskin, E. and Karp, S. A. (1971) "A Manual for the Embedded Figures Test", Consulting Psychologists Press, Palo Alto, California.

Wright, D. S. (1988), "Moving Road Freight More Efficiently", Transport, May.

Wright, D. S. and Cross, A. K. (1985), "Information Technology and the Freight Transport Industry", Final Report, Centre for Transport Studies, Cranfield Institute of Technology.

Wright, M. G. (1973), "Discounted Cash Flow", McGraw-Hill Book Company (UK), Maidenhead, Berkshire, England.

Wunderlich, J.; Collette, M.; Levy, L. (1992), "Scheduling Meter Readers for Southern California Gas Company", Interfaces, Vol. 22, No. 3, May/June, pp. 22-30.

Yin, R. Y. (1984), "Case Study Research, Design and Methods", Sage Publications, Beverly Hills, London, New Delhi.

Zand, D. E. and Sorensen R. E. (1975), "Theory of Change and the Effective Use of Management Science", Administration Science Quarterly, Vol. 20, December, pp. 532-545.

Zeller, R. A. and Carmines, E. G. (1978), "Statistical Analysis of Social Data", Rand McNally College Publishing Company, Chicago.

Ziegler, H.-J.; Niemeier, H.-V. and Schrenk, H. (1988), "Computergestützte Transport- und Tourenplanung, Optimierung bei Fahrzeugeinsatz und bei der Gestaltung von Transportanlagen", Kontakte & Studium, Band 223, Expert Verlag.

Zielinski, E. L. (1984), "Computerised Vehicle Routing and Driver Work Standards in a Delivery Fleet Operation", Annual International Industrial Engineering Conference

Proceedings, Industrial Engineering & Management Press (Publisher), Chicago Ill., USA, pp. 561-569.

Zmud, R. W. (1979a), "Individual Differences and MIS Success: A Review of the Empirical Literature", Management Science, Vol. 25, No.10, pp. 966-979.

Zmud, R. W. (1979b), "An Information Processing Conceptualization of the Systematic-Heuristic Cognitive Style", Working Paper, Department of Information Systems, Georgia State University.

Appendices

Appendix 1: Indicators used for measuring research variables

A-

The following *Likert type five-point scale* has been used for all indicators listed under "A-". The use of the scale is illustrated in Figure A1-1.

Below you will find a number of statements concerning benefits arising from the route planning software in various areas of physical distribution/other than physical distribution. Please indicate to what extent the given statements apply to your company using the following five-point scale of measurement:

1 = Statement applies very strongly

2 = Statement applies strongly

3 = Statement applies somewhat

4 = Statement applies a little

5 = Statement does not apply at all

The use of the route planning software has led to:

Increased consistency of planning results.

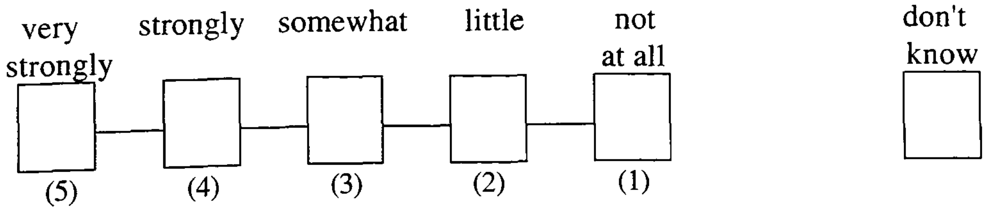

Figure A1-1: Example of an indicator based on a Likert type five-point scale

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A-188a. Reduced overtime for drivers as a result of more accurate planning.

A-188b. Comprehensive and effective interactive planning options, e.g. planning variable routes etc., repeated generation of route proposals, inserting last minute calls into already planned routes, time-efficient moving of customers between routes or amalgamating of trips etc.

A-188c. Increased consistency of planning results.

A-188d. Significant reduction in paper work/delivery notes. This may be the case, if your previous route planning system consisted of a wholly manual planning approach using, for example the "pigeon hole" system, i.e. sorting delivery notes according to fixed routes. Using route planning software allowed you substantially to reduce the amount of daily paper work processed.

A-188e. Quicker planning process.

A-188f. Quicker appraisal of "make or buy decisions", i.e. deciding on the usage of company owned vehicles or contract vehicles on the basis of calculated (usually variable) costs of transport operations.

A-188g. Reduced occurrence of errors (e.g. wrong account numbers, inaccurate delivery weight etc.) which have be caused by wrong or inaccurate data entry, omission of order paper, bad handwriting etc.

A-188h. Improved compliance with legal regulations, e.g. drivers' working/resting time, the maximum loading weight of the vehicle etc.

A-188i. More effective coping with delivery constraints, e.g. customer time windows, access restrictions etc.

A-188j. Extended period of order collection/acceptance. This is achieved because the use of route planning software allows the daily orders to be planned within a significantly shorter time.

A-188k. Emergency orders/late orders can be inserted into the computer or route plan within minutes and easily added to existing routes. Please note that this item refers to the situation where routes have already been generated by the software, but the assembling and loading of vehicles has <u>not</u> yet begun.

A-188l. Reduced duplication of data entry and the associated occurrence of errors. During manual route planning, the data describing the planned routes needed to be inserted manually into other software systems, e.g. stock control software, software for generating picking and loading lists etc. Using route planning software allows this to be done automatically ultimately improving the efficiency and effectiveness of the other aforementioned software systems.

A-188m. Smoother work procedures in the warehouse. Since the daily work load is planned in a substantially shorter time, there is more <u>time</u> available in the warehouse for order picking, load assembling and vehicle loading.

A-188n. Reduced overtime for warehouse staff. This is achieved, because route planning requires less time (see above) which allows the warehouse staff to start working earlier in the day.

A-188o. Route planning software removes the drudgery of manual route planning leaving route planners free to use their expertise to carry out their job more effectively.

A-188p. Decreased dependence on the scheduler resulting in easier replacement in case of illness, absence during holidays, or leaving the company.

A-188q. Reduced time period required for learning the task of vehicle route planning.

A-188r. Improved control over the transport operation through, e.g. the provision of time schedules including driving time, time spent on the customers' premises loading and unloading of vehicles etc.

A-188s. Improved monitoring of the vehicle scheduler's work performance. The route planning software provides management with reports including information on daily and weekly performance standards, e.g. number of vehicles used, total mileage covered, total vehicle utilisation by weight and time etc.

A-188t. Improved monitoring of drivers' working hours. The route planning software provides management with reports including information on drivers' working hours or vehicle utilisation by time. This information enables management to curtail the drivers' habit of finishing early, thus making full use of the vehicles and human resources available.

A-188u. Improved availability and statistical analysis of distribution data representing useful management information. For example, daily and weekly route statistics including number of drops, mileage covered, average utilisation of vehicles, average speeds, average delivery per customer, order frequency per customer, transport volume per mile etc.

A-188v. Improved transparency of costs involved in transport operations and subsequently increased general cost awareness in physical distribution.

A-189a. Improved customer service through, e.g. fewer omitted orders, shorter lead time, keeping to more precise time schedules.

A-189b. Increased potential for the acquisition of future customers using improved customer service as a competitive advantage.

A-189c. Improved ability to conduct simulations of transport operations indicating the impact of customer restrictions (service expectations) on the "quality" of routes/transport costs. On the basis of this information the marketing department can determine the general customer service level or negotiate certain service levels with individual customers.

A-189d. Planned data (cost/time) of the transport operation provided by the software can be compared with real data in order to indicate possible plan deviations. This allows an increased analysis and control of transport cost efficiency.

A-189e. Improved availability of cost information for assessing customers in terms of transport costs per delivered unit, order, etc. Cost information regarding customers can be used by the marketing department (see above).

A-189f. Comprehensive and effective planning options for tactical and strategic route planning issues, e.g.: - determining a cost effective vehicle fleet in terms of size and fleet mix, - determining a cost effective depot structure in terms of number, size and location of depots, - determining a cost effective allocation of customers to depots.

A-189g. Spreading the delivery work over the available drivers on a more equal basis. This in turn leads to fairer remuneration (payroll) of the work force.

A-189h. Improved information in relation to driving time and working time on customers' sites, used by the payroll software for the calculation of drivers' remuneration.

The following *semantic differential seven-point scale* has been used for all indicators listed under "B- to O-". The use of the scale is illustrated in Figure A1-2.

How user friendly/unfriendly is the route planning software?

	very	quite	slightly	neither/ equally	slightly	quite	very		don't know
user friendly	☐	☐	☐	☐	☐	☐	☐	user unfriendly	☐
	(7)	(6)	(5)	(4)	(3)	(2)	(1)		

Figure A1-2: Example of an indicator based on a semantic differential seven-point scale

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B-

B-1. How high/low is your COMPANY`S awareness of the existence of route planning software currently available on the market?

B-2. How high/low is your COMPANY`S awareness of the benefits of route planning software currently available on the market?

B-3. How high/low is your COMPANY`S awareness of the development and progress made in computerised route planning over recent years?

C-

C-5. Generally speaking, how <u>high/low</u> did YOU initially (prior to installation) consider the usefulness of route planning software?

C-6d. Generally speaking, how <u>high/low</u> did your DRIVERS initially (prior to installation) consider the usefulness of route planning software?

C-7. How <u>important/unimportant</u> did YOU initially (prior to installation) judge the use of route planning software for your company's physical distribution?

C-8d. How <u>important/unimportant</u> did your DRIVERS initially (prior to installation) judge the use of route planning software for your company's physical distribution?

C-9. How <u>high/low</u> did YOU initially (prior to installation) estimate the benefits arising from commercial route planning software?

C-10d. How <u>high/low</u> did your DRIVERS initially (prior to installation) estimate the benefits arising from commercial route planning software?

C-10xm. (Managers' CVRS pre-attitude index composed of C-5, C-7, C-9)

C-10xs. (Schedulers' CVRS pre-attitude index composed of C-5, C-7, C-9)

C-10y. (Drivers' CVRS pre-attitude index composed of C-6d, C-8d, C-10d)

C-34. How <u>capable/incapable</u> did YOU initially (prior to installation) believe the route planning software would be of dealing with the delivery constraints of your transport operations?

C-35. How financially <u>justifiable/unjustifiable</u> did YOU initially (prior to installation) consider it would be to install the route planning software at all of your organisation's distribution sites, i.e. production facility warehouses and (external) distribution depots? If your organisation has only one distribution site, please tick the box "item does not apply".

C-36. How organisationally <u>feasible/infeasible</u> did YOU initially (prior to installation) consider it would be to install the route planning software at all of your organisation's distribution sites, i.e. production facility warehouses and (external) distribution depots? If your organisation has only one distribution site, please tick the box "item does not apply".

C-37. How <u>capable/incapable</u> did YOU initially (prior to installation) believe the route planning software would be at achieving cost savings due to an improved allocation of customers to distribution depots?

C-38i. Some companies believe that variable routes (delivery patterns) commonly associated with commercial route planning packages hinder order picking and assembly. This is because these tasks can only be carried out after the last order entry and subsequent development of routes. In other words, order picking and assembly can no longer be carried out smoothly throughout the day. How concerned/unconcerned were YOU initially (prior to installation) about the above mentioned issue?

C-39. How willing/unwilling did YOU initially (prior to installation) believe the majority of your customers would be in accepting a change in the service level (e.g. change of delivery times, delivery frequencies etc.) associated with the use of route planning software?

C-40i. How concerned/unconcerned were YOU initially (prior to installation) that the aforementioned change in the service level would be unpopular with some of your customers and result in some sort of loss of their goodwill?

C-41. To what extent (high/low) did YOU initially believe that your customers would perceive the use of the route planning software to be beneficial in terms of enhancing the customer service level, e.g. via an increased delivery reliability?

C-42. How high/low did YOU initially (prior to installation) estimate the route planning software's ability to deal with late customer orders, i.e. orders which come in after the normal route planning routine has been terminated? Please note that this question refers to the situation where routes have already been generated by the software, but the assembling and loading of vehicles not yet begun.

C-43. How small/large did YOU initially (prior to installation) estimate the scale of investment of time and resources that would have to be made for the collection, input and adjustment of customer data?

C-44. How high/low did YOU initially (prior to installation) estimate would be the accuracy (in terms of driving time and mileage) of the computer generated routes compared with actual routes?

C-45i. Cost savings due to vehicle fleet size reductions cannot be achieved by the use of route planning software, because the fleet needs to meet seasonal fluctuations in demand. How right/wrong would YOU initially (prior to installation) have classified this judgement?

C-74. How good/bad did YOU initially (prior to installation) judge the relative balance between the cost and the expected usefulness of route planning software? The costs include any costs related to providing the resources, including money, time, manpower, and opportunity. The usefulness includes any benefits that arise from the use of the software, e.g. direct and indirect cost savings as well as intangible benefits, e.g. improved customer service and better control over transport operations of the vehicles.

C-75. How high/low did YOU initially (prior to installation) perceive the nominal sum of the total software investment costs, including the costs for the software implementation? Please note that nominal costs are costs relative to your transport department's available financial resources (budget).

C-81. How concerned/unconcerned were YOU initially (prior to installation) about the compatibility of the route planning software with other computer hardware systems (e.g. mainframe computer, personal computers, printers etc.) and software systems (e.g. database systems) which were already available in your company?

D-

D-12. How favourable/unfavourable would YOU describe the general policy of your DRIVERS' union towards management decisions which affect your drivers' work, e.g. changes in work routines, payroll, software installations etc.? If your drivers are not unionised, please tick the box "item does not apply".

D-13. How favourable/unfavourable was the reaction of your DRIVERS' union towards the planned introduction of the route planning software? If your drivers are not unionised, please tick the box "item does not apply".

D-14. How favourable/unfavourable was the reaction of your DRIVERS' non-work based union representative (e.g. unions' regional or area officer) towards the planned introduction of the route planning software?

D-15. How favourable/unfavourable was the reaction of your DRIVERS' work-based union representative (e.g. shop steward) towards the planned introduction of the route planning software? If your drivers do not have a work-based union representative, please tick the box "item does not apply".

D-17. How favourable/unfavourable would you describe the general policy of the DISTRIBUTION STAFF'S union towards management decisions which affect the staff's work e.g. changes in work routines, payroll, software installations etc.? If your distribution staff are not unionised, please tick the box "item does not apply".

D-18. How favourable/unfavourable was the reaction of your DISTRIBUTION STAFF'S union towards the planned introduction of the route planning software? If your distribution staff are not unionised, please tick the box "item does not apply".

D-19. How favourable/unfavourable was the reaction of the DISTRIBUTION STAFF'S non-work based union presentative (e.g. unions' regional or area officer) towards the planned introduction of the route planning software? If your distribution staff are not unionised, please tick the box "item does not apply".

D-20. How favourable/unfavourable was the reaction of the DISTRIBUTION STAFF'S work-based union representative (e.g. shop steward) towards the planned introduction of the route planning software? If your distribution staff do not have a work-based union representative, please tick the box "item does not apply".

E-

E-22. How centralised/decentralised is the decision making authority of your local TRANSPORT DEPARTMENT? For instance, the decision making authority is very centralised, if decisions concerning corporate investments or organisational changes in your local transport function are strongly influenced by other functions at a higher level of business hierarchy, e.g. the organisation's board of directors, head office, regional centres etc. On the other hand, the decision making authority is very decentralised, if decisions concerning the aforementioned issues can be made by the local transport department itself.

E-23i. How high/low is your local TRANSPORT DEPARTMENT'S decision making authority regarding the purchase of information technology at a local level?

E-23x. (Centralisation index composed of indicators E-22, E-23i)

E-24. How strong/weak is the involvement of your DATA PROCESSING DEPARTMENT (or informal data processing group) or any other equivalent TECHNICAL DEPARTMENT (e.g. logistics department, business systems department) in decisions concerning the purchase of information technology in your local transport department? If you have no data processing department (or informal data processing group) or any other equivalent technical department, please tick the box "item does not apply".

F-

F-27. To what extent (high/low) does the overall COMPANY POLICY emphasise the general importance of corporate investment in information technology?

F-28. To what extent (high/low) does the overall COMPANY POLICY emphasise the importance of corporate information technology investment in your transport function?

F-29. How high/low is the priority given by your general CORPORATE INVESTMENT POLICY to information technology in transport compared with other functions of your company? For example, if a high priority is given, this means that corporate information technology investment in your transport function is given higher importance than in other functions.

F-31. To what extent (high/low) were some of the distribution data required for the software setup initially (prior to installation) readily available in the form of computer files or physical documents? Distribution data are, e.g. technical vehicle data, average driving speeds according to road types, customer opening times, access restrictions to customer premises etc.

F-32. To what extent (high/low) are responsibilities of staff and management documented in detailed job descriptions?

F-62. How high/low did YOU initially (prior to installation) estimate the importance of transport cost information, e.g. costs per delivered unit, costs per mile etc., as a means for controlling your transport operations?

F-67. How high/low did YOU initially (prior to installation) consider the benefits arising from data transaction systems? Typical data transaction systems are, for example order processing software, finance accounting software etc.

F-68. How high/low did YOU initially (prior to installation) consider the benefits of decision support systems? Typical decision support systems are, for example route planning software, demand forecast software, budget planning software etc.

F-69. How willing/unwilling were YOU initially (prior to installation) to use the information technology which was already available in your company? Information technology includes any kind of computer hardware and software.

F-72. How successful/unsuccessful were most of the route planning software installations YOU initially (prior to installation) knew of?

G-

G-187 (see "V-187")

H-

H-1m. (Satisfaction index of managers composed of indicators: H-149, H-157, H-159, H-166, H-168, H-169, H-170)

H-1s. (Satisfaction index of schedulers composed of indicators: H-149, H-157, H-159, H-166, H-168, H-169, H-170)

H-1d. (Satisfaction index of drivers composed of indicators: H-151d, H-158d, H-161d, H-167d)

H-88. How user friendly/unfriendly is the route planning software?

H-89. How good/bad are the software's interactive features (e.g. option to interfere in the data processing routines at any time, repeated run of selected parts of route planning procedures etc.)?

H-90 How high/low is the extent of control over the program operations, i.e. the comprehensives of the available software features and parameters?

H-91. How intelligible/not-intelligible is the command structure/language (i.e. set of vocabulary, syntax and grammatical rules) used to interact with the software?

H-92. How efficient/inefficient is the command structure/language (i.e. set of vocabulary, syntax and grammatical rules) used to interact with the software?

H-93. How good/bad is the software's flexibility, i.e. its capacity to change or to adjust in response to new conditions, demands, circumstances?

H-94. How good/bad are the error recovery facilities, i.e. the methods and applications governing correction and rerun of software outputs that are incorrect?

H-95. How high/low is the software's response time, i.e. elapsed time between a user-request for service or action and a reply to that request?

H-96. How good/bad are the software's facilities for protection against data loss?

H-97. How good/bad are the software's standard facilities for protection against unauthorised access?

H-98. How high/low is the consistency of the software's planning results?

H-99. How high/low is the reliability of the software's planning results?

H-100. How high/low is the comprehensives of the software's output information (reports)?

H-101. How clear/unclear is the layout and display of the software's output content (reports)?

H-102. How effective/ineffective are the software's facilities to control the display format of reports, e.g. labels, titles, column size, decimal placement etc.?

H-103. How high/low are the benefits of the software's array of graph formats, e.g. line, bar, histogram, pies, multiple plots etc.?

H-104. How high/low are the benefits of the software's data analysis features using statistical methods? For example: Daily and weekly route statistics including number of drops, mileage covered, average utilisation of vehicles, average speeds, average delivery per customer, order frequency per customer, transport volume per mile etc.

H-105. How good/bad is the documentation of the software?

H-106. Generally speaking, how capable/incapable is the route planning software of dealing with the delivery constraints of your transport operations? Delivery constraints are, e.g. vehicle capacity restrictions, customer opening times, access restrictions to customer premises, transport regulations etc.

H-107. How capable/incapable is the route planning software of dealing with customer time windows?

H-108. How capable/incapable is the route planning software of dealing with vehicle access restrictions to customer premises?

H-109. How positively/negatively does the route planning software affect the route quality (in terms of driving time, vehicle mileage and vehicle utilisation) compared with manual route planning?

H-110. How technically convenient/inconvenient was it to interface the route planning software with existing software systems (possibly via the mainframe computer), e.g. order entry and processing system, stock control system etc.?

H-111. How technically convenient/inconvenient is the daily, weekly etc. data (customer orders) transfer from the computerised order entry and processing system (possibly via the mainframe) to the route planning software system?

H-112. How fast/slow is the daily, weekly etc. data (customer orders) transfer from the computerised order entry and processing system (possibly via the mainframe) to the route planning software system?

H-113. How capable/incapable is the route planning software of effectively allocating customers to depots? If the software is not used for this purpose, please tick the box "item does not apply".

H-114. How short/long is the average time which is required by the route planning software to process the daily, weekly etc. customer orders, i.e. generating the final set of feasible routes?

H-115. How accurate/inaccurate are the computer generated routes in terms of mileage and driving time compared with actual routes?

H-116. How accurately/inaccurately does the software's road network reflect the actual infrastructure of your company's delivery area?

H-117. How flexible/inflexible is the software's road network in being adapted to the infrastructure of the delivery area?

H-118. How good/bad was the adaptability of the route planning software to the computer hardware and software as well as peripheral machines (e.g. mainframe computer, printers etc.) available in your company?

H-125. How positively/negatively does YOUR operating a sophisticated computer system affect your self-esteem?

H-127. How satisfied/unsatisfied are YOU with the aforementioned change in the level of your responsibilities?

H-128. How positively/negatively has the work atmosphere (in terms of, e.g. the level of disputes etc.) between YOU (scheduler) and MANAGEMENT changed since the installation of the route planning software?

H-129. How positively/negatively has the work atmosphere (in terms of, e.g. the level of disputes etc.) between YOU (scheduler) and the DRIVERS changed since the installation of the route planning software?

H-130. How much easier/more difficult do YOU perceive your work under the use of the route planning software compared with the previous manual route planning system?

H-134. How satisfied/unsatisfied were YOU with changes in your work routine induced by the route planning software? If no such changes have occurred, please tick the box "item does not apply".

H- 135. How satisfied/unsatisfied were YOU with changes in your work environment induced by the route planning software? If no such changes have occurred, please tick the box "item does not apply.

H-136. How many more/fewer areas and issues of vehicle route planning have YOU been able to engage in since you have been using the route planning software?

H-137. How interesting/disinteresting do YOU find the use of the route planning software?

H-138. How challenging/unchallenging do YOU perceive the new demands presented by the use of the route planning software?

H-145. How high/low do YOU judge the usefulness of the route planning software for performing your job?

H-149. Overall, how satisfied/unsatisfied are YOU with the route planning software?

H-151d. Overall, how satisfied/unsatisfied are your DRIVERS with the applied use of the route planning software?

H-152d. How much easier/more difficult do your DRIVERS perceive their work under the use of the route planning software compared with the previous manual route planning system?

H-153d. How positively/negatively did the route planning software affect your DRIVERS' self-esteem, because of their company using computerised route planning?

H-154d. How satisfied/unsatisfied were your DRIVERS with changes in their work routine induced by the route planning software? If no such changes have occurred, please tick the box "item does not apply".

H-155. How positively/negatively has the work atmosphere (in terms of, e.g. the level of disputes etc.) between YOU (Manager) and the SCHEDULER(S) changed since the installation of the route planning software?

H-156. How positively/negatively has the work atmosphere (in terms of, e.g. the level of disputes etc.) between YOU (Manager) and your DRIVERS changed since the installation of the route planning software?

H-157. Generally speaking, how happy/unhappy do YOU feel about your company's use of route planning software?

H-158d. Generally speaking, how happy/unhappy do your DRIVERS feel about your company's use of route planning software?

H-159. How high/low do YOU consider the usefulness of the route planning software for your company's specific distribution environment?

H-161d. How high/low do your DRIVERS judge the usefulness of the route planning software for your company's specific distribution environment?

H-163d. How high/low do your DRIVERS judge the usefulness of the route planning software for performing their job?

H-166. In retrospect, to what extent (high/low) would YOU still support the introduction of the route planning software?

H-167d. In retrospect, to what extent (high/low) would your DRIVERS still support the introduction of the route planning software?

H-168. Overall, how superior/inferior is the use of the current route planning software compared with the previous manual route planning procedure?

H-169. How high/low is the software's capability of meeting your company's overall requirements in physical distribution associated with vehicle route planning?

H-170. If the system is used in an OPERATIONAL role, how high/low is the software's capability of meeting your transport operations' specific requirements in vehicle route planning? Operational (day-to-day) route planning includes, e.g.: Daily routing and scheduling of vehicles, optimisation of single routes, insertion of last minutes calls to existing routes etc. If the software is not used for operational route planning, please tick the box "item does not apply".

I-

I-119. How high/low was the depth and detail of the analysis of your company's physical distribution environment (size of vehicle fleet, customer base, existing hardware, special delivery constraints etc.) in order to identify the exact requirements which would have to be met by a route planning package?

I-120. To what extent (high/low) was the compatibility of the software with your work procedures (working times, responsibilities, procedures such as data transfer from the sales department to the route planning software etc.) analysed prior to installation?

I-121. How well/badly do YOU (managers) think the implementation of the route planning software was organised and planned?

I-123. How strong/weak was the top management's emphasis (degree of interest, enthusiasm, support, participation etc.) on the implementation of the route planning software?

I-124. To what extent (high/low) has the implementation of the route planning software been guided by a project leader? If the software implementation was not guided by a project leader, please tick the box "item does not apply".

I-125. To what extent (high/low) did the aforementioned leader possess decision making authority coming from a high level in the business hierarchy? If the software implementation was not guided by a project leader, please tick the box "item does not apply".

I-126. To what extent (high/low) did the aforementioned leader possess technical competence? If the software implementation was not guided by a project leader, please tick the box "item does not apply".

I-127. To what extent (high/low) had the VEHICLE SCHEDULER(S) been informed at an early stage about the introduction of the route planning software?

I-128. To what extent (high/low) have the DRIVERS been informed at an early stage about the introduction of the route planning software?

I-129. How high/low was the VEHICLE SCHEDULERS`(S`) overall involvement in the implementation process of the route planning software?

I-130. How high/low was your DRIVERS' overall involvement in the implementation process of the route planning software? The drivers' involvement would, for example comprise their collecting of customer data, discussing the computer generated routes with the vehicle scheduler in order to fine tune the software parameters etc.

I-132. How high/low was YOUR (managers) conviction that any organisational and technical problems occurring during the software implementation would eventually be overcome? Organisational problems concern, e.g. the data collection, entry and fine tuning, customer reactions, industrial relations etc. Technical problems concern, e.g. the data transfer, restrictions in the data base capacity, software interfaces etc.

I-133. How high/low was the VEHICLE SCHEDULER'S(S') conviction that any organisational and technical problems occurring during the software implementation would eventually be overcome? Organisational problems concern, e.g. the data collection, entry and fine tuning, customer reactions, industrial relations etc. Technical problems concern e.g. the data transfer, restrictions in the data base's capacity, software interfaces etc.

I-134. How high/low was YOUR (managers) commitment and ambition to solve any of the aforementioned problems until the route planning software produced satisfactory results?

I-135. How high/low was the SCHEDULER'S(S') commitment and ambition to solve any of the aforementioned problems until the route planning software produced satisfactory results?

I-136. How high/low was your DRIVERS' conviction that any problems occurring during the software implementation would eventually be overcome? The following or similar problems may have occurred: The route planning software initially suggested the use of inappropriate, i.e. slow, narrow, incorrect, roads and generated "odd" route proposals. Your drivers were unable to meet the indicated working standards (e.g. driving time). The software did not accurately meet certain delivery restrictions, e.g. customer time windows.

I-137. How high/low was your DRIVERS' commitment and ambition to support the software project, e.g. reporting inaccuracies of proposed routes and schedules, until the route planning software produced satisfactory results?

I-143. To what extent (high/low) was the collection, input and adjustment of the software parameters (e.g. driving speed, customer location etc.) conducted accurately and in great detail?

I-144. To what extent (high/low) did the implementation of the route planning software induce changes in customer delivery times, delivery frequencies etc.? If no changes have occurred, please tick the box "item does not apply".

I-145. Following the completion of the full software implementation, to what extent (high/low) has an evaluation taken place of the systems success in meeting the initial objectives?

I-146. To what extent (high/low) have any identified deviations from the set objectives been corrected if any such have occurred ? If no deviations have occurred, please tick the box "item does not apply".

I-147. To what extent (high/low) was the route planning software handed over to the VEHICLE SCHEDULER'S(S') responsibility once the software was fully implemented?

I-148. To what extent (high/low) are the software parameters being kept up to date, i.e. constantly adjusted to changes occurring in the distribution environment? Software parameters are, e.g. road speed, road access, customer opening times, loading and unloading times at customers premises, vehicle etc.

J-

J-154 How good/bad is YOUR understanding of the currently used route planning software?

J-155. How high/low do YOU estimate your ability to use the route planning software's full range of functions relevant to your COMPANY`S specific transport operations?

J-156. How high/low do YOU estimate your ability to use the route planning software at its full potential?

J-156x. (System operators' performance index composed of indicators J-154 to J-156)

J-157i. To what extent (high/low) do YOU feel that there is scope for improving your ability to operate the route planning software?

K-

K-177d. Generally speaking, to what extent (high/low) are the DRIVERS keen to meet the working standards (allocated working times, proposed route sequences etc.) indicated by the computer generated routes/schedules?

K-178d. Generally speaking, to what extent (high/low) do your DRIVERS actually meet the working standards (allocated working times, proposed route sequences etc.) indicated by the computer generated routes/schedules?

L-

L-97. To what extent (high/low) did YOU receive computer training on the route planning software?

L-98. How sufficient/insufficient would YOU judge your computer training on the route planning software?

L-98x. (Training index composed of indicators L-97 and L-98)

M-

M-56. How high/low was YOUR general comprehension of computers before the installation of route planning software?

M-57. To what extent (high/low) did YOU initially (prior to installation) use computers?

M-57x. (Computer literacy index composed of indicators M-56 and M-67)

M-58. To what extent (high/low) did YOUR educational (college/in-house) training provide you with knowledge about computers, computer-based information systems and/or electronic data processing?

N-

N-63p. How good/bad is YOUR personal relationship with your DRIVERS?

N-64p. How good/bad is YOUR working relationship with your DRIVERS?

N-65p. How high/low would YOU describe the level of confidence which the drivers have in you?

N-65px. (Relationship schedulers-drivers index composed of indicators N-63p to N65p)

O-

The following list includes some basic requirements of a vehicle route planning software package. Please indicate how important/unimportant the listed requirements were for your site/company/depot with regard to approving the present software?

O-1. Reasonable investment costs.

O-2. High user friendliness.

O-3. Overriding facility for adding late customer orders.

O-4. Highly flexible road network which can easily be adapted to the road infrastructure of your delivery area

O-5. High compatibility with existing hardware and software systems.

O-6. High availability of interactive features (e.g. option to interfere in the data processing routines at any time, repeated run of selected parts of route planning procedures etc.).

O-7. Accurate road network using true distances.

O-8. Sophisticated route graphics.

O-9. Availability of comprehensive analysis features, i.e. statistics or reports including management information. For example: Daily and weekly route statistics including drivers' working times, number of drops, mileage covered, average utilisation of vehicles, average speeds, average delivery per customer, order frequency per customer, transport volume per mile etc.

O-10. High technical flexibility, i.e. its capacity to change or to adjust in response to new conditions, demands, circumstances.

O-11. High data processing speed.

O-12. Quick response time, i.e. elapsed time between a user request for service or action and a reply to that request.

O-13. Convenient interface to existing software/hardware.

The following list includes a number of potential objectives (expected benefits) of using vehicle route planning software. Please indicate how important/unimportant these objectives were for your particular organisation or distribution site when you first implemented the route planning software.

O-14. Reducing vehicle mileage.

O-15. Increasing the vehicle utilisation by weight, i.e. delivering a larger quantity of goods per vehicle.

O-15. Increasing the vehicle utilisation by time, i.e. using vehicles longer per day.

O-17. Reducing costs for office staff by, e.g. saving one vehicle scheduler or allowing the vehicle scheduler(s) to conduct additional work tasks (job-enrichment).

O-18. Facilitating the route planning procedure, i.e. releasing the vehicle scheduler from manually adding up delivery weights and volumes as well as sorting through heaps (piles) of consignment notes.

O-19. Increasing the route planning speed, i.e. reducing the amount of time required to generate a daily set of routes.

O-20. Reducing the amount of paperwork to be processed.

O-21. Avoiding the occurrence of errors caused by, e.g. the omission of delivery notes, bad handwriting etc.

O-22. Increasing the availability of transport information.

O-23. Improving the ability to cope with delivery constraints, e.g. transport regulations, customer time windows etc.

O-24. Reducing the duplication of work effort/data entry and the associated occurrence of errors. This aims to improve the efficiency of existing software systems, e.g. stock control system, software for generating picking and loading lists etc.

O-25. Enhancing the customer service level by, e.g. an improved delivery reliability (decreased omission of customer orders), improved keeping the customers opening times etc.

O-26. Decreasing the company's dependence on the vehicle scheduler, i.e. making him more easily replaceable by a substitute member of staff.

O-27. Reducing the time period required for learning the task of vehicle route planning.

O-28. Improving the control over the transport operation through, e.g. the provision of a time schedule including driving time, time spent on the customers' premises, loading and unloading of vehicles etc.

O-29. Improving the transparency of costs involved in transport operations and subsequently increasing the general cost awareness in physical distribution.

O-30. Improving the availability and statistical analysis of distribution data thus providing useful management information (trend analysis, reporting etc.).

P-

Indicator: P-191

The following list includes a number of commercial route planning software packages. Please indicate to what extent you are aware of these software packages by ticking the boxes as appropriate.

Tick **box "1"**, if you have **only heard about the existence** of the route planning software but have no further knowledge of the software's prices or feature.

Tick **box "2"**, if you are aware the software packages' **technical features** or **capabilities**.

Tick **box "3"**, if you are aware of the software packages' **prices** and their features/capabilities, you should tick box 2 and box 3.

Package name (producer)	**I have only heard of the software**	**I am aware of the features**	**I am aware of the purchase price**
Trandos (PE International)	1	2	3
Roadshow (RTSI Routing Technology Software Inc.)	1	2	3
Optrac (Lowscan Ltd.)	1	2	3
Paragon2 (Paragon Software Systems)	1	2	3
DiPS (Distribution Planning Systems)	1	2	3
Routemaster (Analytical Systems)	1	2	3
Visit (Istel Ltd.)	1	2	3
Dayload (Synergy Logistics Ltd)	1	2	3
Loadstar (Davies & Robinson Software Ltd)	1	2	3
Truckstops2 (Micro Analytics Inc/ Kingswood Ltd.)	1	2	3
Vehicle routing and scheduling (Tim Harpner)	1	2	3
Alpha (Rainsford Logistics Ltd)	1	2	3
H.V.R.P. (Hawell, Dillon Computing and Management Service Ltd.)	1	2	3
Mover (London University)	1	2	3
Pathmaster (ICL)	1	2	3
Triplan (Applied Transport Simulation)	1	2	3
Trucks (Deltran Analysis Ltd.)	1	2	3
Vanplan (Scicon Computer Services)	1	2	3
Minipath (Scicon Computer Services)	1	2	3
VSPX (IBM)	1	2	3
Other: ______________________	1	2	3

Q-

Indicator: Q-190a

What was the turnover achieved by your site's secondary distribution fleet in the financial year 1990/91?

If your company is a subsidiary of a brewing group, this item refers to your company as a subsidiary and not the total brewing group.
Please specify the turnover in £. If you are reluctant or unable to specify an exact figure, you may also specify an approximate sum in terms of a range, for example your turnover was £50,000,000 - £60,000,000.

[ ] £ turnover in 1990/91

Indicator: Q-190b

What was the total sales volume in tonnes achieved by your site's secondary distribution fleet in the financial year 1990/91?

If your company is a subsidiary of a brewing group, this item refers to your company as a subsidiary and not the total brewing group.

[ ] tonnes of sales in 1990/91

Indicator: Q-190c

What is the average number of daily customer orders?

[ ] Average daily customer orders.

Indicator: Q-190d

Please specify the number, type, gross vehicle weight and maximum loading/carrying capacity of

a) company owned vehicles and b) contract vehicles currently available on your site (where you are located!).

A) COMPANY OWNED VEHICLES

Number **Type (artic/rigid) / Gross vehicle weight / Max. loading/carrying capacity**

[ ] ______________________________

[ ] ______________________________

[ ] ______________________________

B) CONTRACT/HIRED VEHICLES

Number **Type (artic/rigid) / Gross vehicle weight / Max. loading/carrying capacity**

[ ] ______________________________

[ ] ______________________________

[ ] ______________________________

R-

Indicator: R-191

Please indicate which of the following technical and financial functions are available on your site in the form of autonomous departments. In addition, indicate for how many years these departments have been in existence:

Years of existence

[] Autonomous data processing department ☐ years

[] Autonomous logistics department ☐ years

[] Autonomous controlling department (controlling is defined as a function concerned with planning, organising, directing/leading, checking (controlling) the company's resources and activities with the aim of optimizing the corporate success. ☐ years

Other technical or financial departments:

[] ______________ **(please specify)** ☐ years

[] ______________ **(please specify)** ☐ years

S-

Indicator: S-42

Are you currently advertising your CVRS system in journals, magazines or other publications or have you done so in the past?

[] No________

[] Yes_______, if yes, please complete the following information:

- When did you start advertising your CVRS system (d d m m y y) ☐☐☐☐☐☐
- Please indicate how often per year and in which publications (journals, magazines etc.) did you advertise your CVRS system over the past seven years. If you have not placed any advertisement in a particular year, please indicate this by filling in the figure "0". If you cannot fully remember the exact number of advertisement placed in a particular year, give a rough estimate indicating "estimate" or you fill in no figure at all indicating "can't remember".

1987: Number of Annual Adverts — Publications (please specify names)

______________ : ______________

1988 Number of Annual Adverts — Publication (please specify names)

______________ : ______________

1989 Number of Annual Adverts — Publication (please specify names)

______________ : ______________

1990: Number of Annual Adverts — Publications (please specify names)

______________ : ______________

1991 Number of Annual Adverts Publication (please specify names)

_______________ : _______________

1992 Number of Annual Adverts Publication (please specify names)

_______________ : _______________

1993 Number of Annual Adverts Publication (please specify names)

_______________ : _______________

In what ways other than via advertisements do you inform the public about the availability and benefits of your CVRS system?

[] Case studies of current users of your CVRS system are published in journals and/or magazines; if yes, please indicate the number of case studies and journals used for publishing these over the past seven years.

____

[] Mailing lists sent to private and public organisation which you believe are potential users of your CVRS system; if yes, please specify below:

____

[] Presentation of your CVRS systems at exhibitions; if yes, please indicate how often and at which exhibitions you have presented your CVRS system over the past seven years.

1987: _______________

1988: _______________

1989: _______________

1990: _______________

1991: _______________

1992: _______________

1993: _______________

[] Presentation of your CVRS systems at conferences/seminars; if yes, please indicate how often and on which conferences/seminars you have presented your CVRS system over the past seven years.

1987: _______________

1988: _______________

1989: _______________

1990: _______________

1991: _______________

1992: _______________

1993: _______________

[] Other marketing channels (please specify): _______________

Indicator: S-192

How did you or your company learn about the availability of route planning software packages?
Several answers are possible. Please tick the small boxes ("[]") as appropriate.

If more than one of the listed sources of information apply, please give a rank order indicating from which source you have obtained most information, second most information etc. as follows:

1 = source from which you obtained most information about the available packages

2 = source from which you obtained the second most information about the available packages

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n = source from which you obtained the least information about the available packages

	Rank order	
[]	____	By reputation/recommendation from a current user of route planning software
[]	____	At exhibitions: ________________ **(please specify)**
[]	____	On conferences/seminars: ________________ **(please specify)**
[]	____	Through advertisements in journals, magazines etc.: ________________ **(please specify name of journal, magazine etc.)**
[]	____	Via mailing lists from software producers
[]	____	Via personal selling, i.e. the software producer had addressed you directly either personally or via the telephone
[]	____	other ________________ **(please specify information source)**

T-

Indicator: T-195x

The following list includes a number of educational and professional qualifications. Please check which of the qualifications apply to YOU.

[] No further qualifications after leaving school

[] O' levels/GCSE

[] A' levels

[] Professional, vocational or technical qualification, e.g. BTEC (Business & Technical Education Council), C & G (City and Guilds), HND, HNC, ONC etc.

[] First degree of higher education

[] Post graduate degree of higher education

[] Other ________________
(Please specify)

U-

Indicator: U-164

For how many years have YOU been directly involved in vehicle route planning in your total professional career?

[ ] Years of direct involvement in vehicle route planning

V-

Indicator: V-187

Did the use of the route planning software directly lead to a reduction in the transport costs per mile covered and/or tonne delivered?

If yes, please specify under a) the reduction in pence/£.

If you are unable to specify the reduction in transport costs achieved as a direct result of using the software, but still think that there has been some reduction, tick answer "b)".

Otherwise, if no reduction in transport costs has been achieved at all as a direct result of using the software, tick answer "c)".

Note that transport costs are defined as **vehicle running** and **standing costs**; they do not include costs for the driving personnel.

a) yes:

reduction of transport costs per mile covered of pence [ ]

reduction of transport costs per tonne delivered of £ [ ]

[] b) yes, the route planning software directly lead to a reduction in the transport costs per mile covered and/or tonne delivered, but is impossible to specify the extent of reduction achieved.

[] c) No reduction in transport costs has been achieved as a direct result of using the route planning software.

W-

Indicator: W-180/181

How much time on average (in man hours) is currently required to plan a full day's load using the route planning software?

Hours

[ ] Currently required time for planning a full day's load using the route planning software

How much time (in man hours) on average used to be required for planning a full day's load prior to the software installation. i.e. when your company was still using either manual route planning or simplistic computer-assisted route planning?

Hours

[ ] Required time for planning a full day's load prior to the introduction of the route planning software

Indicator: W-182

Did the use of the route planning software directly lead to a reduction (in %) in the annual mileage of the vehicle fleet?

The reduction in mileage may be the result of a more flexible allocation of orders to vehicles. A further relevant factor may be the reduction in extra mileage. During manual route planning or route planning using a simplistic order allocation software (usually run on the mainframe computer), such extra mileage may have occurred from somewhat rigid route planning procedures or the inability to deal efficiently with delivery constraints (e.g. customer time windows, access restrictions etc).

If possible, please specify under **"a)"** the approximate annual reduction in percentage terms and/or miles achieved as a direct result of using the route planning software.

If you are unable to specify the approximate reduction in mileage, but still think that there has been some reduction, tick answer **"b)"**.

Otherwise, if no reduction in mileage at all has been achieved as a direct result of using the software, tick answer **"c)"**.

	%	**miles**
a) Reduction in mileage per annum:		

[] b) A reduction in mileage has been achieved as a direct result of using the route planning software. However, it is impossible to specify the extent of reduction achieved.

[] c) No savings in mileage have been achieved as a direct result of using the route planning software.

Indicator: W-183

Did the use of the route planning software directly lead to an increase of the utilisation by weight of your multiple drop vehicles, which usually include 17 tonne gvw drays with a loading capacity of 9 to 10 tonnes each?

The reduction in mileage may have been the result of a more flexible allocation of orders to vehicles and greatly enhanced planning option offered by the route planning software.

If possible, please specify under **"a)"** the approximate increase in vehicle utilisation by weight (in %) of your multiple drop vehicles.

If you are unable to specify the approximate increase in vehicle utilisation by weight achieved as a direct result of using the software, but still think that there has been some increase, tick answer **"b)"**.

Otherwise, if no increase of vehicle utilisation by weight at all has been achieved as a direct result of using the software, tick answer **"c)"**.

	%
a) Increase in vehicle utilisation by weight achieved as a direct result of using the route planning software	**(please specify)**

[] b) An increase in vehicle utilisation by weight has been achieved as a direct result of using the route planning software. However, it is impossible to specify the of extent of increase achieved.

[] c) No increase in vehicle utilisation by weight has been achieved as a direct result of using the route planning software.

Indicator: W-184

Did the use of the route planning software directly lead to an increase in the vehicle utilisation by time of your multiple drop vehicles, which usually include 17 tonne gvw drays with a loading capacity of 9 to 10 tonnes each?

The increased vehicle utilisation by time may have been the result of greatly enhanced planning options offered by the route planning software. Therefore, vehicles are used more effectively in terms of time available. Instead of drivers finishing early, they are sent out for a further trip, if the time available allows for this.

Please specify under **"a)"**, if possible, the approximate increase in vehicle utilisation by time (in %) of your multiple drop vehicles.

If you are unable to specify the approximate increase in vehicle utilisation by time achieved as a direct result of using the software, but still think that there has been some increase, tick answer **"b)"**.

Otherwise, if no increase of vehicle utilisation by time has been achieved at all as a direct result of using the software, tick answer **"c)"**.

a) Increase in vehicle utilisation by time achieved as a direct result of using the route planning software — % [ ] **(please specify)**

[] b) An increase in vehicle utilisation by time has been achieved as a direct result of using the route planning software. However, it is impossible to specify the of extent of increase achieved.

[] c) No increase in vehicle utilisation by time has been achieved as a direct result of using the route planning software.

Indicator: W-185

Did the use of the route planning software lead to a reduction in the number of delivery vehicles?

A reduction in the vehicle fleet size usually is a result of an increase in the aforementioned vehicle utilisation by weight and time.

Please note that vehicles may have been saved either directly or indirectly. Vehicles are saved directly by transferring to other operating departments within the organisation, selling or other methods of disposal. Vehicles are saved indirectly by no longer replacing old or written off vehicles.

Please note, furthermore, that vehicles are being saved if:

1) either the number of vehicles was effectively (directly/indirectly) reduced as mentioned above,
2) or, despite an increase of work load due to e.g. rising order volume, no additional vehicle needed to be purchased.

[] yes

[] no

Please indicate the numbers and types of vehicles which were saved as a direct result of introducing the route planning software.

IMPORTANT NOTE: If you are unable to specify the exact number of vehicles saved, please specify the minimum number of vehicles saved adding "MIN" after the figure(s).

Number	Type (artic/rigid) / Gross vehicle weight / Max. loading/carrying capacity

Indicator: W-186

Vehicles saved in relation to number of vehicles prior to use of CVRS (information was collected during telephone conversation)

Appendix 2: Additional statistics

Indicators (label)	n	Median		Mean		Standard Deviation	
A-188i	37	4	4*	3.4	3.8*	1.3	1.0*
A-188b	37	3	3*	3.1	3.3*	0.9	0.8*
A-188c	37	3	3*	3.1	3.3*	1.0	0.8*
A-188g	36	3	3*	2.6	3.1*	1.2	1.0*
A-188d	34	2	3*	2.5	3.0*	1.3	1.1*
A-188o	36	3	3*	2.8	3.1*	1.0	0.8*
A-188h	34	2	3*	2.3	3.0*	1.2	0.8*
A-188r	35	3	3*	2.9	3.2*	1.1	0.8*
A-189d	33	3	3*	2.8	3.1*	1.1	0.9*
A-188u	36	3	4*	3.0	3.5*	1.4	1.0*
A-188v	36	3	3*	2.6	3.4*	1.3	0.9*
A-188s	37	3	3*	2.9	3.3*	1.2	0.9*
A-188t	36	2	3*	2.3	2.9*	1.2	0.9*
A-188p	36	3	3*	3.0	3.4*	1.3	1.1*
A-188q	36	2.5	3*	2.6	2.9*	1.1	0.9*
A-188m	36	2.5	3*	2.6	3.0*	1.2	0.9*
A-189g	33	2	3*	2.5	3.0*	1.2	1.0*
A-188l	35	3	3*	2.8	3.3*	1.2	0.8*
A-189a	35	3	3*	2.7	3.1*	1.1	0.8*
A-189b	36	3	3*	2.7	3.2*	1.2	0.9*
A-188j	35	2	3*	2.2	3.0*	1.2	0.7*
A-188k	36	2	3*	2.4	3.0*	1.2	0.9*
A-189c	32	2	3*	2.4	3.1*	1.3	0.9*
A-189e	29	2	2*	2.0	2.8*	1.1	1.0*
A-189h	29	1	2.5*	1.8	2.9*	1.2	1.2*

Table A2-1: Additional measures of intangible benefits in operational CVRS

Indicator (label)	n	Me-dian	Mean	St. Dev.	Indicator (label)	n	Me-dian	Mean	St. Dev.
H-149	96	6	5.3	1.6	H-106	96	6	5.2	1.7
H-151d	38	4	3.8	1.6	H-107	96	6	5.2	1.8
H-157	96	6	5.9	1.1	H-108	93	6	5.1	1.9
H-158d	38	4	3.8	1.2	H-109	88	6	5.4	1.4
H-159	95	6	5.8	1.3	H-110	47	6	4.7	2.1
H-161d	37	4	3.7	1.3	H-111	71	6	5.3	1.9
H-166	95	6	5.9	1.4	H-112	76	6	5.1	2.0
H-167d	38	4	3.4	1.2	H-113	13	6	4.5	2.4
H-168	78	6	5.6	1.9	H-114	92	5	4.7	1.7
H-169	94	6	5.2	1.5	H-115	95	6	5.4	1.5
H-170	92	6	5.0	1.6	H-116	91	6	5.6	1.4
H-88	77	6	5.5	1.3	H-117	84	6	5.6	1.3
H-89	73	6	5.0	1.8	H-118	47	6	5.4	1.6
H-90	62	6	5.1	1.5	H-134	34	6	5.0	1.5
H-91	60	6	5.3	1.4	H-154d	34	3	3.1	1.2
H-92	59	6	5.5	1.0	H-135	33	5	5.1	1.6
H-93	68	6	5.0	1.7	H-127	38	5	5.1	1.3
H-94	59	5	4.6	1.6	H-136	50	4	4.4	1.3
H-95	75	5	5.0	1.5	H-145	54	6	5.6	1.4
H-96	65	6	5.3	1.7	H-163d	37	4	3.4	1.3
H-97	64	6	5.0	1.9	H-155	36	4	4.2	0.8
H-98	72	5	4.8	1.8	H-156	36	4	3.9	0.8
H-99	71	6	4.9	1.8	H-128	37	4	4.3	1.0
H-100	73	6	5.4	1.2	H-129	35	4	3.9	1.2
H-101	72	6	5.8	1.2	H-130	38	5	4.4	2.0
H-102	54	4	4.0	1.9	H-152d	38	3.5	3.4	1.3
H-103	43	2	3.3	2.1	H-125	53	4	5.0	1.5
H-104	58	5	4.2	2.2	H-153d	37	4	4.0	1.0
H-105	61	5	4.9	1.6	H-137	55	6	5.9	1.2
					H-138	38	6	5.9	1.2

Table A2-2: Additional measures of *CVRS user satisfaction*

Indicator (label)	Current + future CVRS users				Current + future CVRS non-users			
	n	Median	Mean	Standard Deviation	n	Me-dian	Mean	Standard Deviation
P-191	17	15	13.6	7.8	20	1	2.55	3.3
B-1	17	6	5.8	1.2	20	5	4.5	2.0
B-2	17	6	5.8	1.2	20	5	4.5	1.9
B-3	17	6	5.4	1.4	20	4.5	4.3	1.9

Table A2-3: Additional measures of *CVRS awareness* variables

Indicator (label)	Current + future CVRS users				Current + future CVRS non-users			
	n	Median	Mean	Standard Deviation	n	Median	Mean	Standard Deviation
C-10xm	17	6	6.2	0.68	20	4.7	4.7	1.6
C-34	17	6	5.6	1.1	20	4	3.8	1.6
C-35	12	5.5	5.1	1.6	8	2	1.8	0.7
C-36	12	6	5.7	1.7	8	4.5	4.4	1.7
C-37	14	5	5.0	1.6	18	4	4.4	1.6
C-38i	17	4	4.3	2.3	20	2.5	3.0	1.8
C-39	15	4	4.2	1.1	20	2	2.9	1.7
C-40i	16	3.5	3.6	1.9	20	2	2.4	1.8
C-41	13	4	3.8	1.4	18	3	2.8	1.4
C-42	17	4	3.8	1.9	17	4	3.9	2.1
C-43	16	3	3.8	1.9	16	3.5	3.8	1.9
C-44	16	6	6.1	1.5	18	5	4.6	1.5
C-45i	17	4	4.2	2.1	20	2.5	3.7	2.1
C-81	14	6	5.4	1.4	15	6	6.1	1.0
C-74	16	6	5.7	0.9	18	5	4.7	1.5
C-75	14	5.5	4.8	1.9	18	5.5	4.8	1.7

Table A2-4: Additional measures of *CVRS pre-attitude variables*

Indicator (label)	Organisational efficiency (Transport cost savings)				
	Savings (SS) Rank	n	No savings (US) Rank	n	Significance level (p) %
I-119	14.1	20	8.7	5	**10**
I-120	14.9	20	8.8	6	**10**
I-121	18.6	26	7.3	6	**1**
I-123	17.9	26	10.5	6	**10**
I-124	13.1	20	9.6	4	ns
I-125	12.6	18	6.5	4	**5**
I-126	11.5	17	8.8	4	ns
I-129	14.4	22	12.4	5	ns
I-130	15.9	25	16.4	6	ns
I-132	18.2	26	9.1	6	5
I-133	16.1	23	7.0	5	**5**
I-136	17.4	25	10.4	6	**10**
I-134	18.1	26	9.8	6	**5**
I-135	16.3	23	6.2	5	**1**
I-137	18.3	26	8.6	6	**5**
I-143	18.2	28	14.3	6	ns
I-145	16.9	24	9.8	6	**10**
I-146	12.7	19	11.8	5	ns
I-148	21.3	32	9.7	6	**1**

SS = Successful systems, i.e. systems which managed to achieve transport cost savings

US = Unsuccessful systems, i.e. systems which failed to achieve transport cost savings

Table A2-5: Additional measures of Kruskal-Wallis test of *hypothesis 7* (pp. 190 - 191)

Dependent variable Dimension	Independent variable Concept	RCC	p (%)	n
+ Actual CVRS awareness	Company size	0.50	**1**	42
+ Actual CVRS awareness	Data centralisation	0.38	**1**	41
CVRS existence (perceived awareness)	Company size	0.09	ns	43
CVRS benefits (perceived awareness)	Company size	0.12	ns	43
CVRS progress (perceived awareness)	Company size	0.23	ns	43
CVRS existence (perceived awareness)	Data centralisation	0.35	**5**	42
CVRS benefits (perceived awareness)	Data centralisation	0.34	**5**	42
CVRS progress (perceived awareness)	Data centralisation	0.37	**5**	42

Table A2-6: Additional measures of Spearman's rank correlation test for *hypotheses 4a* and *4b* (p. 163)

Indicator (label)	Savings (SS)				No savings (US)			
	n	Median	Mean	Standard Deviation	n	Median	Mean	Standard Deviation
Satisxx1m	33	6.1	6.0	0.6	7	5	4.7	1.5
Satisxx1s	40	5.7	5.6	1.0	9	5.3	4.3	2.0
Satisxx1d	30	3.9	3.9	1.2	7	2.9	3.2	1.0
SS = Successful systems, i.e. systems which managed to achieve transport cost savings								
US = Unsuccessful systems, i.e. systems which failed to achieve transport cost savings								

Table A2-7: Additional measures of *CVRS user satisfaction* indices

Indicator (label)	Organisational efficiency (Transport cost savings)				
	Savings (SS) Rank	n	No savings (US) Rank	n	Significance (p) %
CVRS operators' performance	24.7	40	26.0	9	ns
Performance A	19.9	30	11.6	6	**10**
Performance B	20.0	30	10.8	6	**5**
SS = Successful systems, i.e. systems which managed to achieve transport cost savings					
US = Unsuccessful systems, i.e. systems which failed to achieve transport cost savings					

Table A2-8: Additional measures of Kruskal-Wallis test of *hypotheses 8b-8c* (pp. 220)

Indicator (label)	Savings (SS)				No savings (US)			
	n	Median	Mean	Standard Deviation	n	Median	Mean	Standard Deviation
K-77d	30	5	4.6	1.3	6	2.5	3.3	2.1
K-178d	30	5.6	5.5	0.9	6	3.8	4.0	1.8
SS = Successful systems, i.e. systems which managed to achieve transport cost savings								
US = Unsuccessful systems, i.e. systems which failed to achieve transport cost savings								

Table A2-9: Additional measures of variables relating to the *drivers' performance* concept

Concept	Median	Mean	Standard deviation
Managers' CVRS satisfaction	6.0	5.7	1.0
Schedulers' CVRS satisfaction	5.7	5.4	1.3
Drivers' CVRS satisfaction	3.9	3.7	1.2
Managers' CVRS pre-attitude	6.0	5.3	1.4
Schedulers' CVRS pre-attitude	5.3	4.8	1.6
Drivers' CVRS pre-attitude	3.0	3.1	1.4

Table A2-10: Additional measures of *CVRS user satisfaction* and *CVRS pre-attitude*

Dimension	Median	Mean	Standard deviation
CVRS operators' performance	6.0	5.7	1.1
CVRS user satisfaction	5.7	5.4	1.3
Educational computer training	2.0	2.9	2.2
CVRS training	4.5	4.1	2.0

Table A2-11: Additional measures of concepts significantly associated with *CVRS operators' performance*

Dependent variable	Independent variable	RCC	p (%)	n
Dimension	Concept			
Drivers' performance A	Drivers' CVRS satisfaction	0.66	**1**	37
+ Drivers' performance B	Drivers' CVRS satisfaction	0.33	**5**	37
Drivers' performance A	Relationship schedulers' - drivers	0.40	**5**	46
+ Drivers' performance B	Relationship schedulers' - drivers	0.28	ns	46

Table A2-12: Additional measures of Spearman's rank correlation test for *hypotheses 12a - 12b* (p. 252)

Measures of *multiple regression analysis*	*Hypotheses 4a - 4b*	*Hypotheses 11a - 11f*
Degrees of freedom (model)	1	2
Degrees of freedom (error))	42	52
Sum of squares (model)	839.5	9.35
Sum of squares (error)	1581.8	51.91
Mean squares (model)	839.5	4.68
Mean squares (error)	37.7	1.00
Standard error of estimate	6.14	1.00
F-ratio (model)	22.29	4.68
P-value (%)	1	1

Table A2-13: Additional measures of multiple regression for *hypotheses 4a - 4b* (p. 275) and *11a - 11f* (p. 280)

Appendix 3: Error estimates of trend analysis for future sales of CVRS installations

Overall, a quadratic function shown in Figure 4.2 (Fitted model of forecasting sales of CVRS installations 1994 - 1998) seems to fit the observations better than an alternative linear or exponential function. This is shown by the generally lower error estimates of the quadratic function.

Type of function	Forecast function	Mean error	Mean square error	Mean absolute error	Mean absolute percentage error	Mean percentage error
Linear	8.75+100.667∗T	0.00	729.60	21.38	5.96	1.52
Quadratic	90.3571+51.7024 ∗ 5.44048 ∗T^2	0.00	108.03	9.55	2.30	-0.18
Exponential	Ex (4.874+0.247∗T)	-3.22	1531	32.10	7.70	-0.40

Table A3-1: Error estimates of trend analysis for future sales of CVRS installations

Appendix 4: Examples of typical data required in CVRS

Depot:

- -name or identification code;
- geographical location;
- daily opening times and closing times;
- vehicle access restrictions.

Vehicles:

- registration/identification number;
- owner status (company owned or sub-contracted);
- type/class; carrying capacity by weight and volume;
- type of vehicle body (e.g. curtain-sided);
- type and number of C02 cylinders;
- pallet loading; mode of loading/unloading (from left side, right side or rear);
- number of drivers required;
- loading and unloading time rates at depot;
- earliest vehicle departure/return time at depot;
- product acceptability;
- cost structure;
- compartments.

Drivers:

- earliest/latest start time;
- earliest/latest return time;
- maximum duty time per day;
- maximum driving time per week;
- maximum duty time to break;
- maximum driving time to break;
- duration of break for a meal;
- drivers' holidays;
- drivers' wages.

Products:

- identification name or code;
- class;
- per unit weight and volume;
- costs/time per loaded or unloaded unit;
- earliest delivery time by product type/class.

Customers:

- identification number;
- address;
- telephone number;

- customer type/class;
- geographical locations;
- delivery zone identification number;
- time per unit loaded/unloaded at premises;
- delivery days and times (time windows);
- vehicle acceptability/access restrictions by customer type;
- class; number of drivers required etc.;
- number of unloading bays or slots;
- special customer information (e.g. "cash customer" or "difficult" customer).

Road network:

- road types to be used;
- average driving speeds per road type;
- accepted road types;
- inter-customers travelling times between customers allocated to identical road nodes;
- travel times and distances for off-map links (distance between customers' geographical locations and their allocated road nodes within the road data base);
- defining geographic sub-areas (zones).

Appendix 5: List of companies which have participated in this research

Allied Breweries Ltd.
Bass Brewers Ltd.
Bateman (George) & Sons Ltd.
Belhaven Brewery Co. Ltd.
BOC Ltd.
Brain (S.A.) & Co. Ltd.
Brakspear (W. H.) & Sons PLC
Burtonwood Brewery PLC
Coca Cola Osnabrück
Courage Ltd.
Crown Brewery PLC
Daufenbach GmbH
Egerland GmbH & Co. KG
Eldridge, Pope & Co. PLC
Fiege GmbH
Fuller, Smith & Turner PLC
Gibbs Mew PLC
Greenalls Retail Divisions
Greene, King & Sons PLC
Guinness, Arthur, Son & Co. Ltd.
Hall & Woodhouse Ltd.
Hardys & Hansons PLC
Hellman GmbH & Co. KG, Gebr.
Ind Coope Burton Brewery Ltd.
Isle of Man Breweries Ltd.
Jennings Brothers PLC
King & Barnes Ltd.
Lees (J. W.) & Co. (Brewers) Ltd.
Mansfield Brewery PLC
Marston, Thompson & Evershed PLC
McMullen & Sons Ltd.
Meyer GmbH
Mitchells of Lancaster (Brewers) Ltd.
Morland & Co. PLC
Nobilia GmbH
Northern Clubs' Federation Brewery Ltd.
Palmer and Harvey Ltd.
Parkbräu AG Primassens
Peroth Ltd.
Randalls Vautier Ltd.
Robinson (Frederic) Ltd.
Schenker GmbH
Scottish & Newcastle Breweries PLC
Shepherd Neame Ltd.
Smith (Samuel) Old Brewery
St. Austell Brewery Co. Ltd.
Taylor (Timothy) & Co. Ltd.
Thwaites (Daniel) PLC
Tollemache & Cobbold Brewery Ltd.
United Buscuits Distribution Services
Vaux Group PLC
Wadworth & Co. Ltd.
Wells, Charles, Ltd.
Whitbread Beer Company
Wolverhampton & Dudley Breweries PLC
Young & Co.'s Brewery PLC

Appendix 6: List of CVRS and CBRS suppliers

CVRS and CBRS supplier	Purchase	£
DAYLOAD*, Synergy Logistics Ltd, Synergy House, Lisle Street, Loughborough LE11 OAY, Tel.: 0509-232706, Fax: 0509-610186, Contact: Andy McMillan	Basic version Maintenance p. a Training Installation Implementation (10 days)	12,000 1,800 840 420 4,200
DiPS*, Distribution Planning Systems, 7 Merganser Way, Kidderminster, Worcester, DY10 4EQ, Tel.: 0299 400528, Fax: 0299 400986, Contact: Vaugn Reid	Basic version Strategic version Daily version Networks (per foreign country) Maintenance p. a Training	6,000 8,000 12,500 5,000 2,500 included
OPTRAK*, Optrak Distribution Software Ltd., 180 Norwood Road, London SE27 9AU, Tel.: 081 - 6711820, Fax: 081 671 4073, Contact: Tim Pigden	Basic version Expansion I Expansion II Maintenance p. a. (% of purchase price) Training	8,000 4,000 8,000 15 (%) --
PARAGON2*, Paragon Software Systems PLC, Allen Court, High Street, Dorking, Surrey, RH4 1AY, Tel: 0306-742100, Fax: 0306-742666, Contact: David Holmes	Basic version Maintenance p. a. Training	19,000 to 31,000 4,000 3,000 to 6,000
ROADSHOW*, RTSI Ltd., 14 Oxford Street, Nottingham, NG1 5BG, England, Tel: 0602-241414, Fax: 0602-474677, Contact: Steve Quarmby	Basic version (according to fleet size) Post code file Multi-day & Multi depot Extended Roadshow Communication & Tracking Hardware workstation Custom installation (per hour) Maintenance p. a. Training (on site) + installation	27,000 to 77,000 6,500 5,500 5,500 6,000 8,000 65 -- 5,000
ROUTEMASTER*, Analytical Systems Ltd., Drayton Gardens, London SW10 9SA, Tel.: 071-244-6077, Fax: 071-373-4801, Contact: Mike Packer	Basic version Maintenance p. a. (% of purchase price) Training	25,500 15 (%) --
TRANDOS*, P-E International PLC, Logistics Division, Park House, Wick Road, Egham, Surrey TW20 0HW, Tel.: 0784-4344, Fax: 0784-37828, Contact: Denis O'Sullivan	Basic version Maintenance p. a. Training	18,000 -- --
* Computerised vehicle routing and scheduling system (CVRS) ** Computerised basic routing systems (CBRS)		

Table A6-1: CVRS and CBRS suppliers

TRUCKSTOPS 2*, Kingswood Ltd., 449 Chiswick High Road, London W4 4AU, Tel: 081-994-5404, Fax: 081-747-8047, Contact: Marry Short	Basic version Maintenance p. a. Training (per day)	5,000 -- 450
VISIT*, AT & T ISTEL Ltd, Highfield House, Headless Cross Drive, Headless Cross, Redditch Worcestershire B97 5EG, Tel.: 0527-550330, Fax: 0527-401483, Contact: Peter Kershaw	Basic version Multi-user Maintenance p. a. (% of purchase price) Training Implementation support (up to)	30,000 50,000 to 100,000 15 (%) 2,500 to 4,000 30,000
AUTOROUTE PLUS**, Nextbase Ltd., Headline House, Chaucer Road, Ashford, Middlesex, TW15 2QT, Tel: 0784-421422, Fax: 0784-420072, Contact: Simon Armstrong	Basic version Maintenance p. a. (Updates) Training (half day)	395 85 300
MILEMASTER**, Automobile Association Developments Ltd., Fanum House, Basingstoke, Hampshire, RG21 2EA, Tel: 0256-493682, Tax: 0256-491792, Contact: Maurice Lay	Basic version Maintenance p. a. (Updates) Training	395 50 --
* Computerised vehicle routing and scheduling system (CVRS) ** Computerised basic routing systems (CBRS)		

Table A6-1 (continued): CVRS and CBRS suppliers